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Infrastructure of audiovisual services – Coding of moving video

Versatile supplemental enhancement information messages for coded video bitstreams

Recommendation ITU-T H.274

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Recommendation ITU-T H.274

Versatile supplemental enhancement information messages for coded video bitstreams

Summary

Recommendation ITU-T H.274 specifies the syntax and semantics of video usability information (VUI) parameters and supplemental enhancement information (SEI) messages for use with coded video bitstreams. The VUI parameters and SEI messages defined in this Recommendation may be conveyed within coded video bitstreams in a manner specified in a video coding specification or may be conveyed by other means as determined by the specifications for systems that make use of such coded video bitstreams. This Recommendation is particularly intended for use with coded video bitstreams as specified by Rec. ITU-T H.266 | ISO/IEC 23090-3, although it is drafted in a manner intended to be sufficiently versatile and generic that it may also be used with other types of coded video bitstreams.

This Recommendation was developed collaboratively with ISO/IEC JTC 1/SC 29 and corresponds with ISO/IEC 23002-7 as technically aligned twin text.

History

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The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

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Introduction

Versions of this Recommendation | International Standard

Recommendation ITU-T H.274 | ISO/IEC 23002-7 version 1 refers to the first approved version of this Recommendation | International Standard. The first edition published by ITU-T as Rec. ITU-T H.274 (08/2020) and by ISO/IEC as ISO/IEC 23002-7:2021 corresponded to the first version.

Recommendation ITU-T H.274 | ISO/IEC 23002-7 version 2 (the current version) refers to the integrated text additionally containing nine additional SEI messages, namely the annotated regions SEI message, the alpha channel information SEI message, the depth representation information SEI message, the multiview acquisition information SEI message, the scalability dimension information SEI message, the extended dependent random access point indication SEI message, the display orientation SEI message, the colour transform information SEI message, and the multiview view position SEI message. Besides these additional SEI messages, the version 2 integrated text also contains corrections to various minor defects in the prior content of the Specification. The second edition published by ITU-T as Rec. H.274 (05/2022) corresponds to the second version. At the time of publication of this edition by ITU-T, a corresponding second edition of ISO/IEC 23002-7 was in preparation for publication by ISO/IEC.

Versatile supplemental enhancement information messages for coded video bitstreams

1 Scope

This Recommendation | International Standard specifies the syntax and semantics of video usability information (VUI) parameters and supplemental enhancement information (SEI) messages. The VUI parameters and SEI messages defined in this Specification are designed to be conveyed within coded video bitstreams in a manner specified in a video coding specification or to be conveyed by other means determined by the specifications for systems that make use of such coded video bitstreams. This Specification is particularly intended for use with coded video bitstreams as specified by Rec. ITU-T H.266 | ISO/IEC 23090-3, although it is drafted in a manner intended to be sufficiently generic that it can also be used with other types of coded video bitstreams.

VUI parameters and SEI messages can assist in processes related to decoding, display or other purposes. However, unless otherwise specified in a referencing specification, the interpretation and use of the VUI parameters and SEI messages specified in this Specification is not a required functionality of a video decoder or receiving video system. Although semantics are specified for the VUI parameters and SEI messages, decoders and receiving video systems can simply ignore the content of the VUI parameters and SEI messages or can use them in a manner that somewhat differs from what is specified in this Specification.

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

– Recommendation ITU-T H.273 (in force) | ISO/IEC 23091-2 (in force), *Coding-independent code points for video signal type identification.*

2.3 Additional references

– Recommendation ITU-T T.35 (in force), *Procedure for the allocation of ITU-T defined codes for non standard facilities.*

– IETF RFC 1321 (in force), *The MD5 Message-Digest Algorithm.*

– IETF RFC 5646 (in force), *Tags for Identifying Languages.*

– ISO/CIE 11664-1 (in force), *Colorimetry – Part 1: CIE standard colorimetric observers.*

– ISO/IEC 10646 (in force), *Information technology – Universal coded character set (UCS).*

– ISO/IEC 11578:1996, *Information technology – Open Systems Interconnection – Remote Procedure Call (RPC).*

3 Definitions

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

3.1 **access unit (AU)**: A set of *PUs* that belong to different *layers* and contain *coded pictures* associated with the same *output time*.

3.2 **adaptation parameter set (APS)**: A *syntax structure* containing *syntax elements* that apply to zero or more *slices* as determined by zero or more *syntax elements* found in *slice headers.*

3.3 **alpha blending**: A process not specified by this Specification, in which an auxiliary *coded picture* is used in combination with a primary *coded picture* and with other data not specified by this Specification in the display process. In an alpha blending process, the samples of an auxiliary *coded picture* are interpreted as indications of the degree of opacity (or, equivalently, the degrees of transparency) associated with the corresponding *luma* samples of the primary *coded picture*.

3.4 **associated IRAP picture (of a particular picture)**: The previous *IRAP picture* in *decoding order* (when present) in the same *layer* as the particular *picture*.

3.5 **azimuth circle**: A circle on a sphere connecting all points with the same azimuth value.

NOTE – An azimuth circle is always a *great circle* like a longitude line on the earth.

3.6 **byte**: A sequence of 8 bits, within which, when written or read as a sequence of bit values, the left-most and right-most bits represent the most and least significant bits, respectively, and the bits are written or read from left to right.

3.7 **chroma**: An adjective, represented by the symbols Cb and Cr, specifying that a sample array or single sample is representing one of the two colour difference signals related to the primary colours.

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

3.8 **coded layer video sequence (CLVS)**: A sequence of *PUs* of the same layer that consists, in *decoding order*, of a *CLVSS PU*, followed by zero or more *PUs* that are not *CLVSS PUs*, including all subsequent *PUs* up to but not including any subsequent *PU* that is a *CLVSS PU*.

3.9 **coded layer video sequence start (CLVSS) PU**: A *PU* in which the *coded picture* is a *CLVSS picture*.

3.10 **coded layer video sequence start (CLVSS) picture**: A *coded picture* that starts a new CLVS as specified in a video coding specification.

NOTE – In Rec. ITU-T H.266 | ISO/IEC 23090-3, a CLVSS picture is an *IRAP picture* with NoIncorrectPicOutputFlag equal to 1 or a gradual decoding refresh picture with NoIncorrectPicOutputFlag equal to 1. In Rec. ITU-T H.265 | ISO/IEC 23008-2, a CLVSS picture is an *IRAP picture* with NoRaslOutputFlag equal to 1.

3.11 **coded picture**: A *coded representation* of a *picture* containing all *CTUs* of the *picture*.

3.12 **coded slice NAL unit**: A *NAL unit* that contains a coded *slice.*

3.13 **coded video bitstream**: A sequence of bits that forms the representation of a sequence of *AUs* forming one or more coded video sequences *(CVSs)*.

3.14 **coded video sequence (CVS)**: A sequence of *AUs* that consists, in *decoding order*, of a *CVSS AU*, followed by zero or more *AUs* that are not *CVSS AUs*, including all subsequent *AUs* up to but not including any subsequent *AU* that is a *CVSS AU*.

3.15 **coded video sequence start (CVSS) AU**: An *AU* that has a PU for each *layer* present in the *CVS* and the *coded picture* in each *PU* is a *CLVSS picture*.

3.16 **component**: An 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.

3.17 **constituent picture**: A part of a spatially *frame*-packed stereoscopic *picture* that corresponds to one view, or a *picture* itself when *frame* packing is not in use or the temporal interleaving *frame* packing arrangement is in use.

3.18 **cropped decoded picture**: The result of cropping a *decoded picture* based on the conformance cropping window for the corresponding *coded picture*.

3.19 **decoded picture**: A *decoded picture* is derived by decoding a *coded picture*.

3.20 **decoder**: An embodiment of a *decoding process*.

3.21 **decoding order**: The order in which *syntax elements* are conveyed in the *coded video bitstream* and are processed by a *decoding process*.

3.22 **decoding process**: The process that reads a *coded video bitstream* and derives *decoded pictures* from it.

3.23 **elevation circle**: A circle on a sphere connecting all points with the same elevation value.

NOTE – An elevation circle is similar to a latitude line on the earth. Except when the elevation value is zero, an elevation circle is not a *great circle* like a longitude circle on the earth.

3.24 **encoder**: An embodiment of an *encoding process*.

3.25 **encoding process**: A process that produces a *coded video bitstream*.

3.26 **field**: An assembly of alternative rows of samples of a *frame*.

3.27 **flag**: A variable or single-bit *syntax element* that can take one of the two possible values: 0 and 1.

3.28 **frame**: The composition of a top *field* and a bottom *field*, where sample rows 0, 2, 4, ... originate from the top *field* and sample rows 1, 3, 5, ... originate from the bottom *field*.

3.29 **global coordinate axes**: The coordinate axes associated with *omnidirectional video* that are associated with an externally referenceable position and orientation.

NOTE – The global coordinate axes could correspond to the position and orientation of a device or rig used for omnidirectional audio/video acquisition as well as the position of an observer's head in the three-dimensional space of the *omnidirectional video* rendering environment.

3.30 **great circle**: The intersection of a sphere and a plane that passes through the centre point of the sphere.

NOTE – A great circle is also known as an orthodrome or Riemannian circle.

3.31 **inter prediction**: An aspect of the *decoding process* for a *coded picture* that makes use of data derived from the *decoding process* of one or more previously decoded *reference pictures*.

3.32 **intra random access point (IRAP) AU**: An *AU* in which each *coded picture* is an *IRAP picture*.

3.33 **intra random access point (IRAP) picture**: A *coded picture* starting from which all *pictures* in the same *layer* in both *decoding order* and *output order* can be decoded without first decoding any *picture* in the same *layer* earlier in *decoding order* in the *coded video bitstream*.

3.34 **layer**: A set of *VCL NAL units* that all have a particular value of layer identifier and the associated non-VCL NAL units, wherein the layer identifier is a variable for which the value is specified by a video coding specification.

NOTE – In the contexts of Rec. ITU-T H.266 | ISO/IEC 23090-3 and Rec. ITU-T H.265 | ISO/IEC 23008-2, the layer identifier is the value of the nuh_layer_id syntax element in the NAL unit header.

3.35 **leading picture (of an IRAP picture)**: A *picture* that is in the same *layer* as the *associated IRAP picture* and precedes the *associated IRAP picture* in *output order*.

3.36 **local coordinate axes**: The coordinate axes having a specified rotation relationship relative to the *global coordinate axes*.

3.37 **luma**: An adjective, represented by the symbol or subscript Y or L, specifying that a sample array or single sample is representing the monochrome signal related to the primary colours.

NOTE – The term luma is used rather than the term luminance in order to avoid implying 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.

3.38 **network abstraction layer (NAL) unit**: A *syntax structure* containing an indication of the type of data that follows and *bytes* containing that data in a manner that enables the extraction of a string of data bits from the syntax structure.

3.39 **network abstraction layer (NAL) unit stream**: A sequence of *NAL units*.

3.40 **non-VCL NAL unit**: A *NAL unit* that is not a *VCL NAL unit*.

3.41 **omnidirectional video**: A video content in a format that enables rendering according to the user's viewing orientation, e.g., if viewed using a head-mounted device, or according to a user's desired *viewport*, reflecting a potentially rotated viewing position.

3.42 **output order**: The order in which the *decoded pictures* are output from the *decoder* (for the *decoded pictures* that are to be output from the *decoder*).

3.43 **output time**: A time when a *decoded picture* is to be output from the *decoder* (for the *decoded pictures* that are to be output from the *decoder*).

3.44 **packed region**: A region in a *region-wise packed picture* that is mapped to a *projected region* according to a *region-wise packing*.

3.45 **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.

NOTE – A picture could be either a frame or a field. However, in one CLVS, either all pictures are frames, or all pictures are fields.

3.46 **picture parameter set (PPS)**: A *syntax structure* containing *syntax elements* that apply to zero or more entire *coded pictures* as determined by a *syntax element* that is the same for all *slices* of a picture and found in the picture header or *slice headers* of each *picture*.

3.47 **picture unit (PU)**: A set of *NAL units* that contain all *VCL NAL units* of a *coded picture* and their associated non-VCL NAL units.

3.48 **projected picture**: A picture that uses a *projection* format for *omnidirectional video*.

3.49 **projected region**: A region in a *projected picture* that is mapped to a *packed region* according to a *region-wise packing*.

3.50 **projection**: A specified correspondence between the colour samples of a *projected picture* and azimuth and elevation positions on a sphere.

3.51 **random access**: The act of starting the decoding process for a *coded video bitstream* at a point other than the beginning of the bitstream.

3.52 **random access skipped leading (RASL) picture**: A *leading picture* that cannot be correctly decoded when the decoding process starts from the *associated IRAP picture*.

3.53 **reference picture**: A *picture* that contains samples that could be used for *inter prediction* in the decoding process of subsequent pictures in decoding order.

3.54 **reference picture list**: A list of *reference pictures* that is used for *inter prediction* of a *slice.*

3.55 **region-wise packed picture**: A decoded picture that contains one or more *packed regions*.

NOTE – A region-wise packed picture could contain a *region-wise packing* of a *projected picture*.

3.56 **region-wise packing**: A transformation, resizing, and relocation of *packed regions* of a *region-wise packed picture* to remap the *packed regions* to *projected region*s of a *projected picture*.

3.57 **sample aspect ratio (SAR)**: The indicated width-to-height aspect ratio of the luma samples of the associated *decoded pictures*.

3.58 **slice**: A region of a *picture* that can be decoded separately from other regions of the same *coded picture* (although in some cases the *decoding process* for the *picture* might use *inter prediction* that makes reference to other previously decoded *reference pictures*).

3.59 **source**: A term used to describe the video material or some of its attributes before encoding.

3.60 **sphere coordinates**: The azimuth and elevation angles identifying a location of a point on a sphere.

3.61 **sphere region**: A region on a sphere, specified either by four *great circles* or by two *azimuth circles* and two *elevation circles*, or such a region on a rotated sphere after applying yaw, pitch, and roll rotations.

3.62 **step-wise temporal sublayer access (STSA) picture**: A *coded picture* that enables up-switching, at the *coded picture*, to the *temporal sublayer* containing the *coded picture*, from the immediately lower *temporal sublayer* of the same *layer* when the *coded picture* does not belong to the lowest *temporal sublayer*.

NOTE – An STSA picture does not use pictures in the same layer and with the same temporal sublayer identifier as the STSA picture for inter prediction reference. Pictures following an STSA picture in decoding order in the same layer and with the same temporal sublayer identifier as the STSA picture do not use pictures prior to the STSA picture in decoding order in the same layer and with the same temporal sublayer identifier as the STSA picture for inter prediction reference. STSA pictures in an independent layer (i.e., a layer that does not depend on other layers in its decoding) always have a temporal sublayer identifier greater than 0.

3.63 **supplemental enhancement information (SEI) message**: A *syntax structure* that provides a particular type of information that assists in processes related to decoding, display or other purposes but is not needed by the *decoding process* in order to determine the values of the samples in *decoded pictures*.

3.64 **syntax element**: An element of data represented in a *syntax structure*.

3.65 **syntax structure**: Zero or more *syntax elements* that are present together in a specified order in a string of data bits, where the left-most bit is considered to be the first and most significant bit, and the right-most bit is considered to be the last and least significant bit.

3.66 **temporal sublayer**: A subset of a temporal scalable *bitstream*, consisting of *VCL NAL units* with a particular value of *temporal sublayer identifier* and the associated *non-VCL NAL units*.

3.67 **temporal sublayer identifier**: A number greater than or equal to 0 defined by a variable for which the value is specified by a video coding specification such that pictures of all *temporal sublayers* have a specified temporal output order relative to each other and pictures with a lower temporal sublayer identifier can be decoded without reference to pictures with a higher temporal sublayer identifier.

3.68 **tilt angle**: The angle indicating the amount of tilt of a *sphere region*, measured as the amount of rotation of a *sphere region* along the axis originating from the sphere origin passing through the centre point of the *sphere region*, where the angle value increases clockwise when looking from the origin towards the positive end of the axis.

3.69 **trailing picture**: A *coded picture* that follows an *IRAP* picture in both decoding order and output order.

3.70 **video coding layer (VCL) NAL unit**: A collective term for *coded slice NAL units* and the subset of other *NAL units* that have *reserved* values of *NAL unit* type identifiers that are classified as VCL NAL units in a referencing specification.

3.71 **video usability information (VUI) parameters**: A syntax structure that identifies properties of interpretation of decoded pictures for display purposes, particularly including colour representation information.

3.72 **viewport**: A region of *omnidirectional video* content suitable for display and viewing by the user.

4 Abbreviations

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

ACI	Alpha Channel Information
APS	Adaptation Parameter Set
AU	Access Unit
CLVS	Coded Layer Video Sequence
CLVSS	Coded Layer Video Sequence Start
CRC	Cyclic Redundancy Check
CTI	Colour Transform Information
CVS	Coded Video Sequence
DRAP	Dependent Random Access Point
DRI	Depth Representation Information
EDRAP	Extended Dependent Random Access Point
FIR	Finite Impulse Response
IRAP	Intra Random Access Point
MAI	Multiview Acquisition Information
NAL	Network Abstraction Layer
PPS	Picture Parameter Set
PU	Picture Unit
RASL	Random Access Skipped Leading
RWP	Region-Wise Packing
SAR	Sample Aspect Ratio
SARI	Sample Aspect Ratio Information
SDI	Scalability Dimension Information
SEI	Supplemental Enhancement Information
STSA	Step-wise Temporal Sublayer Access
VCL	Video Coding Layer
VUI	Video Usability Information

5 Conventions

5.1 General

The term "this Specification" is used to refer to this Recommendation | International Standard.

The word "shall" is used to express mandatory requirements for conformance to this Specification. When used to express a mandatory constraint on the values of syntax elements or the values of variables derived from these syntax elements, it is the responsibility of the encoder to ensure that the constraint is fulfilled.

The word "may" is used to refer to behaviour that is allowed, but not necessarily required.

The word "should" is used to refer to behaviour of an implementation that is encouraged to be followed under anticipated ordinary circumstances, but is not a mandatory requirement for conformance to this Specification.

Content of this Specification that is identified as "informative" does not establish any mandatory requirements for conformance to this Specification and is thus not considered an integral part of this Specification. Informative remarks in the text are, in some cases, set apart and prefixed with the word "note" or "NOTE".

The word "reserved" is used to specify that some values of a particular syntax element are for future use by ITU-T | ISO/IEC and shall not be used in syntax structures conforming to this version of this Specification, but could potentially be used in syntax structures conforming to future versions of this Specification by ITU-T | ISO/IEC.

The word "unspecified" is used to describe some values of a particular syntax element to indicate that the values have no specified meaning in this Specification and are not expected to have a specified meaning in the future as an integral part of future versions of this Specification.

The mathematical operators used in this Specification are similar to those used in the C programming language. However, the results of integer division and arithmetic shift operations are defined more precisely, and additional operations are defined, such as exponentiation and real-valued division.

Numbering and counting conventions generally begin from 0, e.g., "the first" is equivalent to the 0-th, "the second" is equivalent to the 1-th, etc.

5.2 Arithmetic operators

+	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.
÷	division in mathematical equations where no truncation or rounding is intended
$\frac{x}{y}$	division in mathematical equations where no truncation or rounding is intended
$\sum_{i=x}^{y} f(i)$	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

5.3 Logical operators

x && y	Boolean logical "and" of x and y
x || y	Boolean logical "or" of x and y
!	Boolean logical "not"
x ? y : z	if x is TRUE or not equal to 0, evaluates to the value of y; otherwise, evaluates to the value of z.

5.4 Relational operators

>	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 syntax element or variable that has been assigned the value "na" (not applicable), the value "na" is treated as a distinct value for the syntax element or variable. The value "na" is considered not to be equal to any other value.

5.5 Bit-wise operators

& 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 non-negative 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 non-negative 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.

5.6 Assignment operators

= assignment operator

++ increment, i.e., *x*++ is equivalent to $x = x + 1$; when used in an array index, evaluates to the value of the variable prior to the increment operation

− − decrement, i.e., *x*− − is equivalent to $x = x - 1$; when used in an array index, evaluates to the value of the variable prior to the decrement operation

+= increment by amount specified, i.e., x += 3 is equivalent to x = x + 3, and x += (−3) is equivalent to x = x + (−3)

−= decrement by amount specified, i.e., x −= 3 is equivalent to x = x − 3, and x −= (−3) is equivalent to x = x − (−3).

5.7 Range notation

x = y..z x takes on integer values starting from y to z, inclusive, with x, y, and z being integer numbers and z being greater than y.

5.8 Mathematical functions

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

Asin(x) trigonometric inverse sine function, operating on an argument x that is in the range of −1.0 to 1.0, inclusive, with an output value in the range of −π÷2 to π÷2, inclusive, in units of radians (2)

Atan(x) trigonometric inverse tangent function, operating on an argument x, with an output value in the range of −π÷2 to π÷2, inclusive, in units of radians (3)

$$\text{Atan2}(\ y, x\ ) = \begin{cases} \text{Atan}\left(\frac{y}{x}\right) & ; \quad x > 0 \\ \text{Atan}\left(\frac{y}{x}\right) + \pi & ; \quad x < 0\ \&\&\ y >= 0 \\ \text{Atan}\left(\frac{y}{x}\right) - \pi & ; \quad x < 0\ \&\&\ y < 0 \\ +\frac{\pi}{2} & ; \quad x == 0\ \&\&\ y >= 0 \\ -\frac{\pi}{2} & ; \quad \text{otherwise} \end{cases} \tag{4}$$

Ceil(x) smallest integer greater than or equal to x. (5)

$$\text{Clip3}(\ x, y, z\ ) = \begin{cases} x & ; \quad z < x \\ y & ; \quad z > y \\ z & ; \quad \text{otherwise} \end{cases} \tag{6}$$

Cos(x) trigonometric cosine function operating on an argument x in units of radians. (7)

Floor(x) largest integer less than or equal to x. (8)

Ln(x) natural logarithm of x (the base-e logarithm, where e is the natural logarithm base constant 2.718 281 828...). (9)

$$\text{Max}(\ x, y\ ) = \begin{cases} x & ; \quad x >= y \\ y & ; \quad x < y \end{cases} \tag{10}$$

Round(x) = Sign(x) * Floor(Abs(x) + 0.5) (11)

$$\text{Sign}(\ x\ ) = \begin{cases} 1 & ; \quad x > 0 \\ 0 & ; \quad x == 0 \\ -1 & ; \quad x < 0 \end{cases} \tag{12}$$

Sin(x) trigonometric sine function operating on an argument x in units of radians (13)

Sqrt(x) square root of x (14)

Tan(x) trigonometric tangent function operating on an argument x in units of radians (15)

5.9 Order of operation precedence

When order of precedence in an expression is not indicated explicitly by use of parentheses, the following rules apply:

– Operations of a higher precedence are evaluated before any operation of a lower precedence.
– Operations of the same precedence are evaluated sequentially from left to right.

Table 1 specifies the precedence of operations from highest to lowest; a higher position in the table indicates a higher precedence.

NOTE – For those operators that are also used in the C programming language, the order of precedence used in this Specification is the same as used in the C programming language.

Table 1 – Operation precedence from highest (at top of table) to lowest (at bottom of table)

operations (with operands x, y, and z)
"x++", "x− −"
"!x", "−x" (as a unary prefix operator)
x^y
"x * y", "x / y", "x ÷ y", "$\frac{x}{y}$", "x % y"
"x + y", "x − y" (as a two-argument operator), " $\sum f(i)$ "
"x << y", "x >> y"
"x < y", "x <= y", "x > y", "x >= y"
"x = = y", "x != y"
"x & y"
"$x \mid y$"
"x && y"
"$x \mid\mid y$"
"x ? y : z"
"x..y"
"x = y", "x += y", "x −= y"

5.10 Variables, syntax elements and tables

Syntax elements in the syntax tables are represented in **bold** type. Each syntax element is described by its name (all lower case letters with underscore characters), and one descriptor for its method of coded representation. The decoding process behaves according to the value of the syntax element and to the values of previously decoded syntax elements. When a value of a syntax element is used in the syntax tables or the text, it appears in regular (i.e., not bold) type.

In some cases, the syntax tables and semantics use the values of other variables derived from the values of syntax elements. Such variables appear in the syntax tables, or text, named by a mixture of lower case and upper case letter and without any underscore characters. Variables starting with an upper case letter are derived for the decoding of the current syntax structure and all depending syntax structures. Variables starting with an upper case letter could, in some cases, be used in the decoding process for later syntax structures without mentioning the originating syntax structure of the variable. Variables starting with a lower case letter are only used within the clause in which they are derived.

In some cases, "mnemonic" names for syntax element values or variable values are used interchangeably with their numerical values. Sometimes "mnemonic" names are used without any associated numerical values. The association of values and names is specified in the text. The names are constructed from one or more groups of letters separated by an underscore character. Each group starts with an upper case letter and could contain more upper case letters.

NOTE – The syntax is described in a manner that closely follows the C-language syntactic constructs.

Functions that specify properties of the current position in the SEI message payload data are referred to as syntax functions. These functions are specified in clause 6.3 and assume the existence of a pointer with an indication of the position of the next bit to be read by the decoding process from the payload data. Syntax functions are described by their names, which are constructed as syntax element names and end with left and right round parentheses including zero or more variable names (for definition) or values (for usage), separated by commas (if more than one variable).

Functions that are not syntax functions (including mathematical functions specified in clause 5.8) are described by their names, which start with an upper case letter, contain a mixture of lower and upper case letters without any underscore character, and end with left and right parentheses including zero or more variable names (for definition) or values (for usage) separated by commas (if more than one variable).

A one-dimensional array is referred to as a list. A two-dimensional array is referred to as a matrix. Arrays can either be syntax elements or variables. Subscripts or square parentheses are used for the indexing of arrays. In reference to a visual depiction of a matrix, the first subscript is used as a row (vertical) index and the second subscript is used as a column (horizontal) index. The indexing order is reversed when using square parentheses rather than subscripts for indexing. Thus, an element of a matrix s at horizontal position x and vertical position y could be denoted either as s[x][y] or as s_{yx}. A single column of a matrix could be referred to as a list and denoted by omission of the row index. Thus, the column of a matrix s at horizontal position x could be referred to as the list s[x].

A specification of values of the entries in rows and columns of an array could be denoted by { {...} {...} }, where each inner pair of brackets specifies the values of the elements within a row in increasing column order and the rows are ordered in increasing row order. Thus, setting a matrix s equal to { { 1 6 } { 4 9 }} specifies that s[0][0] is set equal to 1, s[1][0] is set equal to 6, s[0][1] is set equal to 4, and s[1][1] is set equal to 9.

Binary notation is indicated by enclosing the string of bit values by single quote marks. For example, '01000001' represents an eight-bit string having only its second and its last bits (counted from the most to the least significant bit) equal to 1.

Hexadecimal notation, indicated by prefixing the hexadecimal number by "0x", is used in some cases instead of binary notation when the number of bits is an integer multiple of 4. For example, 0x41 represents an eight-bit string having only its second and its last bits (counted from the most to the least significant bit) equal to 1.

Numerical values not enclosed in single quotes and not prefixed by "0x" are decimal values.

A value equal to 0 represents a FALSE condition in a test statement. The value TRUE is represented by any value different from zero.

5.11 Text description of logical operations

In the text, a statement of logical operations as would be described mathematically in the following form:

```
if( condition 0 )
   statement 0
else if( condition 1 )
   statement 1
...
else /* informative remark on remaining condition */
   statement n
```

is typically described in the following manner:

... as follows / ... the following applies:

– If condition 0, statement 0
– Otherwise, if condition 1, statement 1
– ...
– Otherwise (informative remark on remaining condition), statement n

Each "If ... Otherwise, if ... Otherwise, ..." statement in the text is introduced with "... as follows" or "... the following applies" immediately followed by "If ... ". The last condition of the "If ... Otherwise, if ... Otherwise, ..." is always an "Otherwise, ...". Interleaved "If ... Otherwise, if ... Otherwise, ..." statements can be identified by matching "... as follows" or "... the following applies" with the ending "Otherwise, ...".

In the text, a statement of logical operations as would be described mathematically in the following form:

```
if( condition 0a    &&    condition 0b )
   statement 0
else if( condition 1a    ||    condition 1b )
   statement 1
...
else
   statement n
```

is typically described in the following manner:

... as follows / ... the following applies:

– If all of the following conditions are true, statement 0:
  – condition 0a
  – condition 0b
– Otherwise, if one or more of the following conditions are true, statement 1:
  – condition 1a
  – condition 1b
– ...
– Otherwise, statement n

In the text, a statement of logical operations as would be described mathematically in the following form:

```
if( condition 0 )
   statement 0
if( condition 1 )
   statement 1
```

is typically described in the following manner:

When condition 0, statement 0

When condition 1, statement 1

5.12 Processes

Processes are used to describe the decoding of syntax elements. A process has a separate specification and invoking. All syntax elements and upper case variables that pertain to the current syntax structure and depending syntax structures are available in the process specification and invoking. A process specification might also have a lower case variable explicitly specified as input. Each process specification has explicitly specified an output. The output is a variable that can either be an upper case variable or a lower case variable.

When invoking a process, the assignment of variables is specified as follows:

– If the variables at the invoking and the process specification do not have the same name, the variables are explicitly assigned to lower case input or output variables of the process specification.

– Otherwise (the variables at the invoking and the process specification have the same name), assignment is implied.

6 Syntax and semantics

6.1 General

This Specification is written in a manner such that it is intended to be referenced by other technical specifications. Such other technical specifications are to be written in a manner to specify certain necessary elements to enable the use of the specified VUI parameters and SEI messages.

Technical specifications that reference this Specification for carrying VUI parameters syntax structure shall specify a container to carry the data of the VUI parameters syntax structure and to identify the length in bits of the VUI parameters syntax structure, e.g., the vui_payload( ) syntax structure specified in Rec. ITU-T H.266 | ISO/IEC 23090-3. The design of the container should provide the ability to detect the number of bits in the vui_parameters( ) syntax structure and to allow the number of bits to be increased in future versions of this Specification, thus enabling this Specification to provide extensibility by directly appending additional syntax elements to the end of the vui_parameters( ) syntax structure in future versions of this Specification. The syntax of the container of the vui_parameters( ) syntax structure is outside the scope of this Specification.

Technical specifications that reference this Specification for carrying SEI messages shall specify a way to carry the payload syntax of each specified SEI message, to identify which SEI message is conveyed, and to identify the length in bits of the SEI message syntax structure, e.g., the sei_payload( ) syntax structure specified in Rec. ITU-T H.266 | ISO/IEC 23090-3 and Rec. ITU-T H.265 | ISO/IEC 23008-2. The design of the container should provide the ability to detect the number of bits in an SEI message and to allow the number of bits to be increased in future versions of this Specification, thus enabling this Specification to provide extensibility by directly appending additional syntax elements to the end of the SEI message syntax structure in future versions of this Specification. The syntax of the container of the SEI messages as well as the method of identifying which SEI message is outside the scope of this Specification.

The length of the VUI parameters syntax structure or an SEI message syntax structure in bits is referred to herein by the variable PayloadBits, which is provided by an external means not specified in this Specification. The number of bytes that contains the payload data is referred to herein by the variable payloadSize, where payloadSize is equal to Ceil(PayloadBits ÷ 8).

For the VUI parameters and most of the SEI messages specified in this version of this Specification (other than the filler payload, user data registered, user data unregistered, and reserved SEI messages), the values of PayloadBits and payloadSize are not used for the parsing of the syntax. However, in some future version of this Specification, the value of PayloadBits or payloadSize could be used as part of the syntax specification for these syntax structures, for example to identify whether payload extension data is present in the VUI parameters or in an SEI message syntax structure that was not specified in an earlier version of this Specification.

The syntax specification in Rec. ITU-T H.266 | ISO/IEC 23090-3 and Rec. ITU-T H.265 | ISO/IEC 23008-2 establishes, under some circumstances, a certain pattern of bits that is used for detecting the value of PayloadBits. It is expected that future versions of this Specification will be written to ensure that such future versions will be compatible with the pattern for extension data that is specified in those other specifications. This pattern is such that when extension data is present and the last bit of such extension data is the last (least significant) bit of a byte, the extension data ends with a byte that contains a bit equal to 1 followed by 7 bits that are equal to 0.

It is a requirement of bitstream conformance to this version of this Specification that the value of PayloadBits, as determined by this external means, shall be equal to the number of bits in the VUI parameters syntax structure or the SEI message syntax structure, as applicable.

It is a requirement of decoder conformance to this version of this Specification that when PayloadBits is greater than the number of bits in the VUI parameters syntax structure or an SEI message syntax structure, the extra data at the end of the VUI or SEI payload data shall be ignored. The semantics for such extra data could potentially be specified in some future version of this Specification.

For example, each SEI message could be carried as a string of data bits that is prefixed with an SEI message payload type indication derived as a payloadType variable within a NAL unit that could contain emulation prevention bytes as specified in Rec. ITU-T H.266 | ISO/IEC 23090-3. When such emulation prevention bytes are present, the emulation prevention bytes are not counted when determining the values of PayloadBits and payloadSize.

6.2 Method of specifying syntax in tabular form

The syntax tables in this Specification specify a superset of the syntax of the VUI parameters and all allowed SEI messages. Additional constraints on the syntax are specified, either directly or indirectly, in other clauses.

The following table lists examples of the syntax specification format. When **syntax_element** appears, it specifies that a syntax element is parsed from the VUI parameters syntax or an SEI message syntax and the data pointer is advanced to the next position beyond the syntax element in the syntax parsing process.

	Descriptor
/* A statement can be a syntax element with an associated descriptor or can be an expression used to specify conditions for the existence, type and quantity of syntax elements, as in the following two examples */	
syntax_element	ue(v)
conditioning statement	
/* A group of statements enclosed in curly brackets is a compound statement and is treated functionally as a single statement. */	
{	
statement	
statement	
...	
}	
/* A "while" structure specifies a test of whether a condition is true, and if true, specifies evaluation of a statement (or compound statement) repeatedly until the condition is no longer true */	
while(condition)	
statement	
/* A "do ... while" structure specifies evaluation of a statement once, followed by a test of whether a condition is true, and if true, specifies repeated evaluation of the statement until the condition is no longer true */	
do	
statement	
while(condition)	

/* An "if ... else" structure specifies a test of whether a condition is true and, if the condition is true, specifies evaluation of a primary statement, otherwise, specifies evaluation of an alternative statement. The "else" part of the structure and the associated alternative statement is omitted if no alternative statement evaluation is needed */	
if(condition)	
primary statement	
else	
alternative statement	
/* A "for" structure specifies evaluation of an initial statement, followed by a test of a condition, and if the condition is true, specifies repeated evaluation of a primary statement followed by a subsequent statement until the condition is no longer true. */	
for(initial statement; condition; subsequent statement)	
primary statement	

6.3 Specification of syntax functions and descriptors

The functions presented in this clause are used in the syntactical description. These functions are expressed in terms of the value of the VUI parameters syntax or an SEI message syntax data pointer that indicates the position of the next bit to be read by the decoding process from the syntax structure.

read_bits(n) reads the next n bits from the syntax structure and advances the data pointer by n bit positions. When n is equal to 0, read_bits(n) is specified to return a value equal to 0 and to not advance the data pointer.

The following descriptors specify the parsing process of each syntax element:

– b(8): byte having any pattern of bit string (8 bits). The parsing process for this descriptor is specified by the return value of the function read_bits(8).

– f(n): fixed-pattern bit string using n bits written (from left to right) with the left bit first. The parsing process for this descriptor is specified by the return value of the function read_bits(n).

– i(n): signed integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the return value of the function read_bits(n) interpreted as a two's complement integer representation with most significant bit written first.

– se(v): signed integer 0-th order Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in clause 9 with the order k equal to 0.

– st(v): null-terminated string encoded as universal coded character set (UCS) transmission format-8 (UTF-8) characters as specified in ISO/IEC 10646. The parsing process is specified as follows: st(v) begins at a byte-aligned position in the bitstream and reads and returns a series of bytes from the bitstream, beginning at the current position and continuing up to but not including the next byte-aligned byte that is equal to 0x00, and advances the bitstream pointer by (stringLength + 1) * 8 bit positions, where stringLength is equal to the number of bytes returned.

  NOTE – The st(v) syntax descriptor is only used in this Specification when the current position in the bitstream is a byte-aligned position.

– u(n): unsigned integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the return value of the function read_bits(n) interpreted as a binary representation of an unsigned integer with most significant bit written first.

– ue(v): unsigned integer 0-th order Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in clause 9 with the order k equal to 0.

7 Video usability information parameters

7.1 General

Clause 7 specifies the syntax and semantics for VUI parameters.

When any information regarding the interpretation of the pictures is not present in the vui_parameters( ) syntax structure, or the vui_parameters( ) syntax structure is not present, there may be some external means that controls the interpretation.

7.2 VUI parameters syntax

vui_parameters(payloadSize) {	**Descriptor**
vui_progressive_source_flag	u(1)
vui_interlaced_source_flag	u(1)
vui_non_packed_constraint_flag	u(1)
vui_non_projected_constraint_flag	u(1)
vui_aspect_ratio_info_present_flag	u(1)
if(vui_aspect_ratio_info_present_flag) {	
vui_aspect_ratio_constant_flag	u(1)
vui_aspect_ratio_idc	u(8)
if(vui_aspect_ratio_idc = = 255) {	
vui_sar_width	u(16)
vui_sar_height	u(16)
}	
}	
vui_overscan_info_present_flag	u(1)
if(vui_overscan_info_present_flag)	
vui_overscan_appropriate_flag	u(1)
vui_colour_description_present_flag	u(1)
if(vui_colour_description_present_flag) {	
vui_colour_primaries	u(8)
vui_transfer_characteristics	u(8)
vui_matrix_coeffs	u(8)
vui_full_range_flag	u(1)
}	
vui_chroma_loc_info_present_flag	u(1)
if(vui_chroma_loc_info_present_flag) {	
if(vui_progressive_source_flag && !vui_interlaced_source_flag)	
vui_chroma_sample_loc_type_frame	ue(v)
else {	
vui_chroma_sample_loc_type_top_field	ue(v)
vui_chroma_sample_loc_type_bottom_field	ue(v)
}	
}	
}	

7.3 VUI parameters semantics

VUI parameters apply to one or more CLVSs.

NOTE 1 – The interpretation of several syntax elements of the VUI parameters are specified by reference to coding-independent code points specified in Rec. ITU-T H.273 | ISO/IEC 23091-2. Further information about the usage of such code points is found in Supplement ITU-T H-Suppl. 19 | ISO/IEC TR 23091-4.

Use of the VUI parameters requires the definition of the following variables:

– A chroma format indicator, denoted herein by ChromaFormatIdc, such that the value 0 indicates that the picture has only a luma component and other values indicate that the picture has three colour components that consist of a luma component and two associated chroma components, such that the width and height of each chroma component are the width and height of the luma component divided by SubWidthC and SubHeightC, respectively, where SubWidthC and SubHeightC are determined from ChromaFormatIdc as specified by Table 2.
– A bit depth for the samples of the luma component, denoted herein by $BitDepth_Y$, and when ChromaFormatIdc is not equal to 0, a bit depth for the samples of the two associated chroma components, denoted herein by $BitDepth_C$.

Table 2 – SubWidthC and SubHeightC values derived from ChromaFormatIdc

ChromaFormatIdc	Chroma format	SubWidthC	SubHeightC
0	Monochrome	1	1
1	4:2:0	2	2
2	4:2:2	2	1
3	4:4:4	1	1

vui_progressive_source_flag and **vui_interlaced_source_flag** are interpreted as follows:

– If vui_progressive_source_flag is equal to 1 and vui_interlaced_source_flag is equal to 0, the source scan type of the pictures should be interpreted as progressive only.
– Otherwise, if vui_progressive_source_flag is equal to 0 and vui_interlaced_source_flag is equal to 1, the source scan type of the pictures should be interpreted as interlaced only.
– Otherwise, if vui_progressive_source_flag is equal to 0 and vui_interlaced_source_flag is equal to 0, the source scan type of the pictures should be interpreted as unknown or unspecified or specified by external means not specified in this Specification.
– Otherwise (vui_progressive_source_flag is equal to 1 and vui_interlaced_source_flag is equal to 1), the source scan type of each picture is indicated at the picture level using the syntax element ffi_source_scan_type in a frame-field information SEI message.

vui_non_packed_constraint_flag equal to 1 specifies that there shall not be any frame packing arrangement SEI messages present in the bitstream that apply to the CLVS. vui_non_packed_constraint_flag equal to 0 does not impose such a constraint.

vui_non_projected_constraint_flag equal to 1 specifies that there shall not be any equirectangular projection SEI messages or generalized cubemap projection SEI messages present in the bitstream that apply to the CLVS. vui_non_projected_constraint_flag equal to 0 does not impose such a constraint.

vui_aspect_ratio_info_present_flag equal to 1 specifies that vui_aspect_ratio_idc is present. vui_aspect_ratio_info_present_flag equal to 0 specifies that vui_aspect_ratio_idc is not present.

vui_aspect_ratio_constant_flag equal to 1 specifies that the values of vui_aspect_ratio_idc, SarWidth, and SarHeight apply to all pictures in the CLVS and there is no SARI SEI message present in the CLVS. vui_aspect_ratio_constant_flag equal to 0 specifies that the values of vui_aspect_ratio_idc, SarWidth, and SarHeight might or might not apply to all pictures in the CLVS and that SARI SEI messages could be present in the CLVS indicating a different sample aspect ratio applicable to the pictures associated with SARI SEI messages. When the vui_aspect_ratio_constant_flag syntax element is not present, the value of vui_aspect_ratio_constant_flag is inferred to be equal to 0.

vui_aspect_ratio_idc, when not equal to 255, indicates the SAR of the luma samples of decoded pictures in the CLVS, unless indicated otherwise by associated SARI SEI messages when vui_aspect_ratio_constant_flag is equal to 0. Its semantics are as specified for the SampleAspectRatio parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2. When the vui_aspect_ratio_idc syntax element is not present, the value of vui_aspect_ratio_idc is inferred to be equal to 0. Values of vui_aspect_ratio_idc that are specified as reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret values of vui_aspect_ratio_idc that are reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 as equivalent to the value 0.

vui_sar_width, when present, indicates the horizontal size of the SAR (in arbitrary units) of the luma samples of decoded pictures in the CLVS, unless indicated otherwise by associated SARI SEI messages when vui_aspect_ratio_constant_flag is equal to 0.

vui_sar_height, when present, indicates the vertical size of the SAR (in the same arbitrary units as vui_sar_width) of the luma samples of decoded pictures in the CLVS, unless indicated otherwise by associated SARI SEI messages when vui_aspect_ratio_constant_flag is equal to 0.

When present, vui_sar_width and vui_sar_height shall be relatively prime or equal to 0. When vui_aspect_ratio_idc is equal to 0 or vui_sar_width is equal to 0 or vui_sar_height is equal to 0, the SAR is unknown or unspecified in this Specification or may be determined by other means, such as the SARI SEI message.

vui_overscan_info_present_flag equal to 1 specifies that the vui_overscan_appropriate_flag is present. When vui_overscan_info_present_flag is equal to 0 or is not present, the preferred display method for the video signal is unknown or unspecified or specified by external means.

vui_overscan_appropriate_flag equal to 1 indicates that the cropped decoded pictures output are suitable for display using overscan. vui_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 2 – For example, vui_overscan_appropriate_flag equal to 1 might be used for entertainment television programming or for a live view of people in a videoconference, and vui_overscan_appropriate_flag equal to 0 might be used for computer screen capture or security camera content.

vui_colour_description_present_flag equal to 1 specifies that vui_colour_primaries, vui_transfer_characteristics, and vui_matrix_coeffs are present. vui_colour_description_present_flag equal to 0 specifies that vui_colour_primaries, vui_transfer_characteristics, and vui_matrix_coeffs are not present.

vui_colour_primaries indicates the chromaticity coordinates of the source colour primaries. Its semantics are as specified for the ColourPrimaries parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2. When the vui_colour_primaries syntax element is not present, the value of vui_colour_primaries is inferred to be equal to 2 (the chromaticity is unknown or unspecified or determined by other means not specified in this Specification). Values of vui_colour_primaries that are identified as reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret reserved values of vui_colour_primaries as equivalent to the value 2.

vui_transfer_characteristics indicates the transfer characteristics function of the colour representation. Its semantics are as specified for the TransferCharacteristics parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2. When the vui_transfer_characteristics syntax element is not present, the value of vui_transfer_characteristics is inferred to be equal to 2 (the transfer characteristics are unknown or unspecified or determined by other means not specified in this Specification). Values of vui_transfer_characteristics that are identified as reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret reserved values of vui_transfer_characteristics as equivalent to the value 2.

vui_matrix_coeffs describes the equations used in deriving luma and chroma signals from the green, blue, and red, or Y, Z, and X primaries. Its semantics are as specified for MatrixCoefficients in Rec. ITU-T H.273 | ISO/IEC 23091-2.

vui_matrix_coeffs shall not be equal to 0 unless both of the following conditions are true:

– $BitDepth_C$ is equal to $BitDepth_Y$.

– ChromaFormatIdc is equal to 3 (the 4:4:4 chroma format).

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

vui_matrix_coeffs shall not be equal to 8 unless one of the following conditions is true:

– $BitDepth_C$ is equal to $BitDepth_Y$,

– $BitDepth_C$ is equal to $BitDepth_Y + 1$ and ChromaFormatIdc is equal to 3 (the 4:4:4 chroma format).

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

When the vui_matrix_coeffs syntax element is not present, the value of vui_matrix_coeffs is inferred to be equal to 2 (unknown or unspecified or determined by other means not specified in this Specification).

vui_full_range_flag indicates the scaling and offset values applied in association with the matrix coefficients. Its semantics are as specified for the VideoFullRangeFlag parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2. When not present, the value of vui_full_range_flag is inferred to be equal to 0.

vui_chroma_loc_info_present_flag equal to 1 specifies that either vui_chroma_sample_loc_type_frame or both vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field are present. vui_chroma_loc_info_present_flag equal to 0 specifies that vui_chroma_sample_loc_type_frame, vui_chroma_sample_loc_type_top_field, and vui_chroma_sample_loc_type_bottom_field are not present.

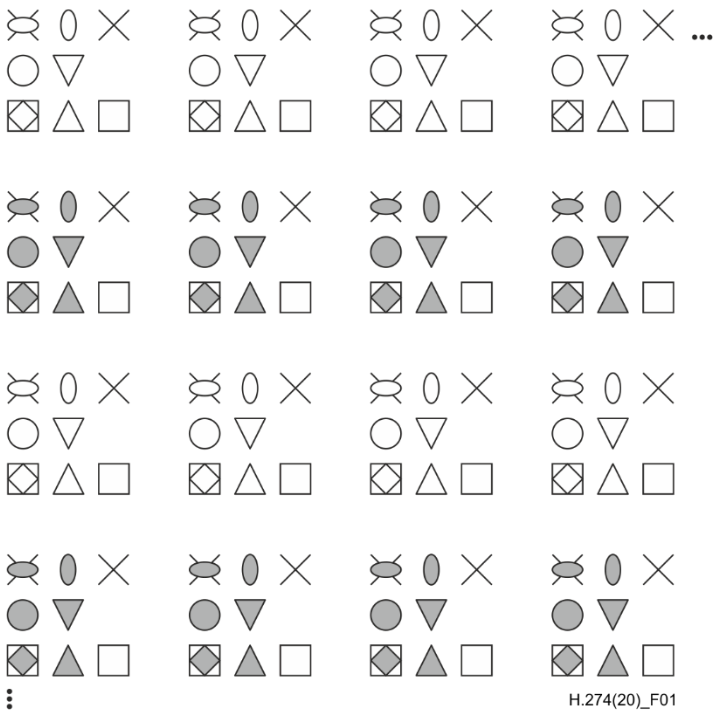
When ChromaFormatIdc is not equal to 1, vui_chroma_loc_info_present_flag should be equal to 0.

vui_chroma_sample_loc_type_frame, **vui_chroma_sample_loc_type_top_field**, and **vui_chroma_sample_loc_type_bottom_field**, when present, specify the location of chroma samples as follows:

– If GeneralProgressiveSourceFlag is equal to 1, GeneralInterlacedSourceFlag is equal to 0, and ChromaFormatIdc is equal to 1 (4:2:0 chroma format), vui_chroma_sample_loc_type_frame specifies the location of chroma samples for both fields of each frame of the CLVS as shown in Figure 1.

– Otherwise, if ChromaFormatIdc is equal to 1 (4:2:0 chroma format), vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field specify the location of chroma samples for each top field and bottom field of the CLVS, respectively, as shown in Figure 1.

– Otherwise (ChromaFormatIdc is not equal to 1), the values of the syntax elements chroma_sample_loc_type, vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field shall be ignored.



Interpretation of symbols

Luma sample position indications:

× Luma sample top field | □ Luma sample bottom field

Chroma sample position indications, where gray fill indicates a bottom field sample type and no fill indicates a top field sample type:

Chroma sample type 2 | Chroma sample type 3

Chroma sample type 0 | Chroma sample type 1

Chroma sample type 4 | Chroma sample type 5

Figure 1 – Location of chroma samples for top and bottom fields for ChromaFormatIdc equal to 1 (4:2:0 chroma format) as a function of vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field in the range of 0 to 5, inclusive

When ChromaFormatIdc is equal to 2 (4:2:2 chroma format), the nominal positions of the chroma samples are co-sited with the corresponding luma samples and the nominal locations in a picture are as shown in Figure 2.

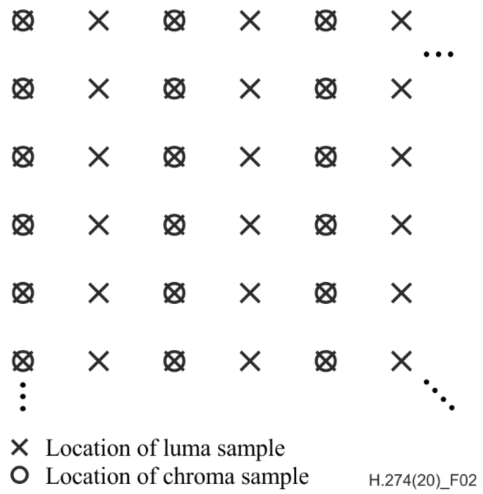


Figure 2 – Nominal vertical and horizontal locations of 4:2:2 luma and chroma samples in a picture

When ChromaFormatIdc is equal to 3 (4:4:4 chroma format), the nominal positions of the chroma samples are such that all array samples are co-sited for all cases of pictures and the nominal locations in a picture are as shown in Figure 3.

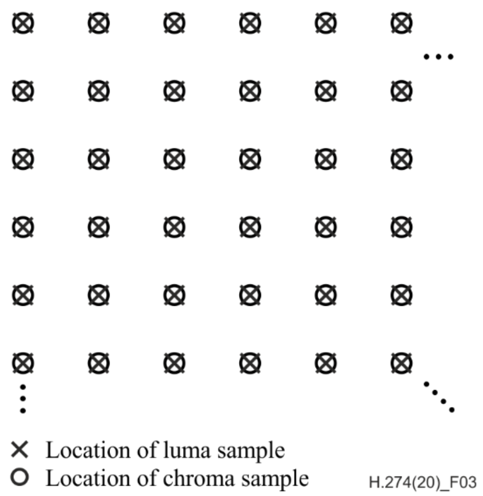


Figure 3 – Nominal vertical and horizontal locations of 4:4:4 luma and chroma samples in a picture

When ChromaFormatIdc is equal to 0, there is no chroma sample array.

When present, the values of vui_chroma_sample_loc_type_frame, vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field shall be in the range of 0 to 6, inclusive.

When ChromaFormatIdc is equal to 1 and vui_chroma_loc_info_present_flag is equal to 0, vui_chroma_sample_loc_type_frame is not present and is inferred to be equal to 6, which indicates that the location of the chroma samples is unknown or unspecified or specified by other means not specified in this Specification. When vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field are not present, the values of vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field are inferred to be equal to vui_chroma_sample_loc_type_frame.

NOTE 3 – In Rec. ITU-T H.266 | ISO/IEC 23090-3 and Rec. ITU-T H.265 | ISO/IEC 23008-2, a nominal chroma sampling type is identified for ChromaFormatIdc equal to 1 that corresponds to vui_chroma_sample_loc_type_frame, vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field equal to 0.

Figure 4 illustrates the indicated relative position of the top-left chroma sample when ChromaFormatIdc is equal to 1 (i.e., the 4:2:0 chroma format), and vui_chroma_sample_loc_type_top_field or vui_chroma_sample_loc_type_bottom_field is equal to the value of a variable Chroma420LocType. The region represented by the top-left 4:2:0 chroma sample (depicted as a large grey, solid-line square with a large grey dot at its centre) is shown relative to the region represented by the top-left luma sample (depicted as a small black square with a small black dot at its centre). The regions represented by neighbouring luma samples are depicted as small grey, dotted-line squares with small grey dots at their centres.

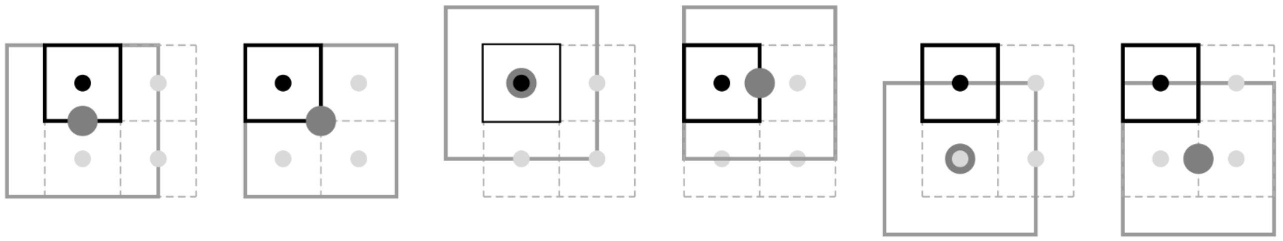


Figure 4 – Location of the top-left chroma sample when ChromaFormatIdc is equal to 1 (4:2:0 chroma format) and Chroma420LocType is equal to 0 to 5, inclusive, from left to right

The relative spatial positioning of the chroma samples, as illustrated in Figure 5, can be expressed by defining two variables HorizontalOffsetC and VerticalOffsetC as a function of ChromaFormatIdc and the variable Chroma420LocType as given by Table 3, where HorizontalOffsetC is the horizontal (x) position of the centre of the top-left chroma sample relative to the centre of the top-left luma sample in units of luma samples and VerticalOffsetC is the vertical (y) position of the centre of the top-left chroma sample relative to the centre of the top-left luma sample in units of luma samples.

In a typical FIR filter design, when ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), HorizontalOffsetC and VerticalOffsetC would serve as the phase offsets for the horizontal and vertical filter operations, respectively, for separable downsampling from 4:4:4 chroma format to the chroma format indicated by ChromaFormatIdc.

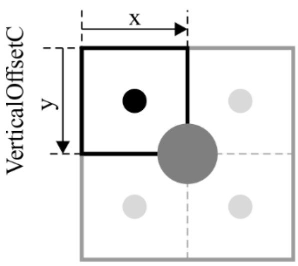


Figure 5 – Location of the top-left chroma sample when ChromaFormatIdc is equal to 1 (4:2:0 chroma format) when Chroma420LocType is equal to 1

Table 3 – Definition of HorizontalOffsetC and VerticalOffsetC as a function of ChromaFormatIdc and Chroma420LocType

ChromaFormatIdc	Chroma420LocType	HorizontalOffsetC	VerticalOffsetC
1 (4:2:0)	0	0	0.5
1 (4:2:0)	1	0.5	0.5
1 (4:2:0)	2	0	0
1 (4:2:0)	3	0.5	0
1 (4:2:0)	4	0	1
1 (4:2:0)	5	0.5	1
2 (4:2:2)	–	0	0
3 (4:4:4)	–	0	0

When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) and the decoded video content is intended for interpretation according to Rec. ITU-R BT.2020 or Rec. ITU-R BT.2100, vui_chroma_loc_info_present_flag should be equal to 1, and vui_chroma_sample_loc_type_frame, vui_chroma_sample_loc_type_top_field, and vui_chroma_sample_loc_type_bottom_field (as applicable) should be equal to 2.

8 SEI messages

8.1 General

Clause 8 specifies the syntax and semantics for SEI messages.

For SEI messages for which the specified syntax structure is empty, such as the dependent random access point SEI message, the mere indication that the SEI message is present (e.g., as indicated by a payload type indicator) is sufficient to convey the associated information (e.g., by indicating that a set of specified constraints are fulfilled).

The semantics and persistence scope for each SEI message are specified in the semantics specification for each particular SEI message.

NOTE – Persistence information for SEI messages is summarized in Table 4.

Table 4 – Persistence scope of SEI messages (informative)

SEI message	Persistence scope
Filler payload	The PU containing the SEI message
User data registered by Rec. ITU-T T.35	Unspecified
User data unregistered	Unspecified
Film grain characteristics	Specified by the syntax of the SEI message
Frame packing arrangement	Specified by the syntax of the SEI message
Display orientation	Specified by the syntax of the SEI message
Referenced parameter sets	The CLVS containing the SEI message
Decoded picture hash	The PU containing the SEI message
Mastering display colour volume	The CLVS containing the SEI message
Colour transform information	Specified by the syntax of the SEI message
Content light level information	The CLVS containing the SEI message
DRAP indication	The picture associated with the SEI message
Alternative transfer characteristics	The CLVS containing the SEI message
Ambient viewing environment	The CLVS containing the SEI message
Content colour volume	Specified by the syntax of the SEI message
Equirectangular projection	Specified by the syntax of the SEI message
Generalized cubemap projection	Specified by the syntax of the SEI message
Sphere rotation	Specified by the syntax of the SEI message
Region-wise packing	Specified by the syntax of the SEI message
Omnidirectional viewport	Specified by the syntax of the SEI message
Alpha channel information	Specified by the syntax of the SEI message
Frame-field information	The PU containing the SEI message
Depth representation information	Specified by the semantics of the SEI message
Multiview acquisition information	The CVS containing the SEI message
Multiview view position	The CVS containing the SEI message
Annotated regions	Specified by the syntax of the SEI message
Sample aspect ratio information	Specified by the syntax of the SEI message
Scalability dimension information	The CVS containing the SEI message
Extended DRAP indication	The picture associated with the SEI message

In the semantics of a particular SEI message, the phrase "the current layer" in the semantics refer to the layer that the particular SEI message is associated with, the phrase "the current picture" refer to the picture that the particular SEI message is associated with, and the phrase "the current CLVS" or "the CLVS" refers to the CLVS containing the current picture. The association of an SEI message to a layer or a picture is specified in a video coding specification that specifies a coded video bitstream with which the SEI messages are used.

The values of some SEI message syntax elements, including fp_arrangement_id and omni_viewport_id, are split into two sets of value ranges, where the first set is specified as "may be used as determined by the application", and the second set is specified as "reserved for future use by ITU-T | ISO/IEC". Applications should be cautious of potential “collisions” of the interpretation for values of these syntax elements belonging to the first set of value ranges. Since different applications might use these IDs having values in the first set of value ranges for different purposes, particular care should be exercised in the design of encoders that generate SEI messages with these IDs having values in the first set of value ranges, and in the design of decoders that interpret SEI messages with these IDs. This Specification does not define any management for these values. These IDs having values in the first set of value ranges might only be suitable for use in contexts in which "collisions" of usage (i.e., different definitions of the syntax and semantics of an SEI message with one of these IDs having the same value in the first set of value ranges) are unimportant, or not possible, or are managed – e.g., defined or managed in the controlling application or transport specification, or by controlling the environment in which bitstreams are distributed.

8.2 Filler payload SEI message

8.2.1 Filler payload SEI message syntax

filler_payload(payloadSize) {	**Descriptor**
for(k = 0; k < payloadSize; k++)	
ff_byte /* equal to 0xFF */	f(8)
}	

8.2.2 Filler payload SEI message semantics

This SEI message contains a series of payloadSize bytes of value 0xFF, which can be discarded.

ff_byte shall be a byte having the value 0xFF.

8.3 User data registered by Rec. ITU-T T.35 SEI message

8.3.1 User data registered by Rec. ITU-T T.35 SEI message syntax

user_data_registered_itu_t_t35(payloadSize) {	**Descriptor**
itu_t_t35_country_code	b(8)
if(itu_t_t35_country_code != 0xFF)	
i = 1	
else {	
itu_t_t35_country_code_extension_byte	b(8)
i = 2	
}	
do {	
itu_t_t35_payload_byte	b(8)
i++	
} while(i < payloadSize)	
}	

8.3.2 User data registered by Rec. ITU-T T.35 SEI message semantics

This SEI message contains user data registered as specified in Rec. ITU-T T.35, the contents of which are not specified in this Specification.

itu_t_t35_country_code shall be a byte having a value specified as a country code by Rec. ITU-T T.35:2000, Annex A.

itu_t_t35_country_code_extension_byte shall be a byte having a value specified as a country code by Rec. ITU-T T.35:2000, Annex B.

itu_t_t35_payload_byte shall be a byte containing data registered as specified in Rec. ITU-T T.35.

The ITU-T T.35 terminal provider code and terminal provider oriented code shall be contained in the first one or more bytes of the itu_t_t35_payload_byte, in the format specified by the Administration that issued the terminal provider code.

Any remaining itu_t_t35_payload_byte data shall be data having syntax and semantics as specified by the entity identified by the ITU-T T.35 country code and terminal provider code.

8.4 User data unregistered SEI message

8.4.1 User data unregistered SEI message syntax

user_data_unregistered(payloadSize) {	**Descriptor**
uuid_iso_iec_11578	u(128)
for(i = 16; i < payloadSize; i++)	
user_data_payload_byte	b(8)
}	

8.4.2 User data unregistered SEI message semantics

This SEI message contains unregistered user data identified by a universal unique identifier (UUID), the contents of which are not specified in this Specification.

uuid_iso_iec_11578 shall have a value specified as a UUID according to the procedures of ISO/IEC 11578:1996, Annex A.

user_data_payload_byte shall be a byte containing data having syntax and semantics as specified by the UUID generator.

8.5 Film grain characteristics SEI message

8.5.1 Film grain characteristics SEI message syntax

film_grain_characteristics(payloadSize) {	**Descriptor**
fg_characteristics_cancel_flag	u(1)
if(!fg_characteristics_cancel_flag) {	
fg_model_id	u(2)
fg_separate_colour_description_present_flag	u(1)
if(fg_separate_colour_description_present_flag) {	
fg_bit_depth_luma_minus8	u(3)
fg_bit_depth_chroma_minus8	u(3)
fg_full_range_flag	u(1)
fg_colour_primaries	u(8)
fg_transfer_characteristics	u(8)
fg_matrix_coeffs	u(8)
}	
fg_blending_mode_id	u(2)
fg_log2_scale_factor	u(4)
for(c = 0; c < 3; c++)	
fg_comp_model_present_flag[c]	u(1)
for(c = 0; c < 3; c++)	
if(fg_comp_model_present_flag[c]) {	
fg_num_intensity_intervals_minus1[c]	u(8)
fg_num_model_values_minus1[c]	u(3)
for(i = 0; i <= fg_num_intensity_intervals_minus1[c]; i++) {	
fg_intensity_interval_lower_bound[c][i]	u(8)
fg_intensity_interval_upper_bound[c][i]	u(8)

for(j = 0; j <= fg_num_model_values_minus1[c]; j++)	
fg_comp_model_value[c][i][j]	se(v)
}	
}	
fg_characteristics_persistence_flag	u(1)
}	
}	

8.5.2 Film grain characteristics SEI message semantics

This SEI message provides the decoder with a parameterized model for film grain synthesis.

NOTE 1 – For example, an encoder could use the film grain characteristics SEI message to characterize film grain that was present in the original source video material and was removed by pre-processing filtering techniques. Synthesis of simulated film grain on the input images, which may be the decoded pictures or converted from the decoded pictures, for the display process is optional and does not need to exactly follow the specified semantics of the film grain characteristics SEI message. When synthesis of simulated film grain on the input images for the display process is performed, there is no requirement that the method by which the synthesis is performed be the same as the parameterized model for the film grain as provided in the film grain characteristics SEI message.

NOTE 2 – The display process is not specified in this Specification.

NOTE 3 – SMPTE RDD 5 specifies a film grain simulator based on the information provided in the film grain characteristics SEI message.

Use of this SEI message requires the definition of the following variables:

– A picture width and picture height in units of luma samples, denoted herein by PicWidthInLumaSamples and PicHeightInLumaSamples, respectively.
– When the syntax element fg_separate_colour_description_present_flag of the film grain characteristics SEI message is equal to 0, the following additional variables:
  – A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.
  – A bit depth for the samples of the luma component, denoted herein by BitDepth_Y, and when ChromaFormatIdc is not equal to 0, a bit depth for the samples of the two associated chroma components, denoted herein by BitDepth_C.

The film grain models specified in the film grain characteristics SEI message are expressed for application to decoded pictures that have 4:4:4 colour format with luma and chroma bit depths corresponding to the luma and chroma bit depths of the film grain model and use the same colour representation domain as the identified film grain model. When the colour format of the decoded video is not 4:4:4 or the decoded video uses a different luma or chroma bit depth from that of the film grain model or uses a different colour representation domain from that of the identified film grain model, an unspecified conversion process is expected to be applied to convert the decoded pictures to the form that is expressed for application of the film grain model.

NOTE 4 – Because the use of a specific method is not required for performing the film grain generation function used by the display process, a decoder could, if desired, down-convert the model information for chroma in order to simulate film grain for other chroma formats (4:2:0 or 4:2:2) rather than up-converting the decoded video (using a method not specified in this Specification) before performing film grain generation.

fg_characteristics_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous film grain characteristics SEI message in output order that applies to the current layer. fg_characteristics_cancel_flag equal to 0 indicates that film grain modelling information follows.

fg_model_id identifies the film grain simulation model as specified in Table 5. The value of fg_model_id shall be in the range of 0 to 1, inclusive. The values of 2 and 3 for fg_model_id 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 ignore film grain characteristic SEI messages with fg_model_id equal to 2 or 3.

Table 5 – fg_model_id values

Value	Description
0	Frequency filtering
1	Auto-regression

fg_separate_colour_description_present_flag equal to 1 indicates that a distinct combination of luma bit depth, chroma bit depth, video full range flag, colour primaries, transfer characteristics, and matrix coefficients for the film grain characteristics specified in the SEI message is present in the film grain characteristics SEI message syntax. fg_separate_colour_description_present_flag equal to 0 indicates that the combination of luma bit depth, chroma bit depth, video full range flag, colour primaries, transfer characteristics, and matrix coefficients for the film grain characteristics specified in the SEI message are the same as indicated in VUI parameters for the CLVS.

NOTE 5 – When fg_separate_colour_description_present_flag is equal to 1, any of the luma bit depth, chroma bit depth, video full range flag, colour primaries, transfer characteristics, and matrix coefficients specified for the film grain characteristics specified in the SEI message could differ from that for the pictures in the CLVS.

When VUI parameters are not present for the CLVS or the value of vui_colour_description_present_flag is equal to 0, and equivalent information to that conveyed when vui_colour_description_present_flag is equal to 1 is not conveyed by external means, fg_separate_colour_description_present_flag shall be equal to 1.

The input image Î, which may be the decoded picture or converted from the decoded picture, used in the equations in this clause is in the same colour representation domain as the simulated film grain signal. Therefore, when any of these parameters does differ from that for the pictures in CLVS, the input image Î used in the equations in this clause would be in a different colour representation domain than that for the pictures in the CLVS. For example, when the value of fg_bit_depth_luma_minus8 + 8 is greater than BitDepth_Y (i.e., the bit depth of the luma component of the pictures in the CLVS), the bit depth of the input image Î used in the equations in this clause is also greater than BitDepth_Y. In such a case, the input image Î would be generated by converting the actual decoded picture to be in the same colour representation domain as the simulated film grain signal. The process for converting an actual decoded picture to the 4:4:4 colour format with same colour representation domain as the simulated film grain signal is not specified in this Specification.

fg_bit_depth_luma_minus8 plus 8 specifies the bit depth used for the luma component of the film grain characteristics specified in the SEI message. When fg_bit_depth_luma_minus8 is not present in the film grain characteristics SEI message, the value of fg_bit_depth_luma_minus8 is inferred to be equal to $\text{BitDepth}_Y - 8$.

The value of fgBitDepth[0] is derived as follows:

$$\text{fgBitDepth}[\ 0\ ] = \text{fg\_bit\_depth\_luma\_minus8} + 8 \tag{16}$$

fg_bit_depth_chroma_minus8 plus 8 specifies the bit depth used for the Cb and Cr components of the film grain characteristics specified in the SEI message. When fg_bit_depth_chroma_minus8 is not present in the film grain characteristics SEI message, the value of fg_bit_depth_chroma_minus8 is inferred to be equal to $\text{BitDepth}_C - 8$.

The value of fgBitDepth[c] for c = 1 and 2 is derived as follows:

$$\text{fgBitDepth}[\ c\ ] = \text{fg\_bit\_depth\_chroma\_minus8} + 8,\ \text{with } c = 1, 2 \tag{17}$$

fg_full_range_flag has the same semantics as specified in clause 7.3 for the vui_full_range_flag syntax element, except as follows:

– fg_full_range_flag specifies the video full range flag of the film grain characteristics specified in the SEI message, rather than the video full range flag used for the CLVS.

– When fg_full_range_flag is not present in the film grain characteristics SEI message, the value of fg_full_range_flag is inferred to be equal to vui_full_range_flag.

fg_colour_primaries has the same semantics as specified in clause 7.3 for the vui_colour_primaries syntax element, except as follows:

– fg_colour_primaries specifies the colour primaries of the film grain characteristics specified in the SEI message, rather than the colour primaries used for the CLVS.

– When fg_colour_primaries is not present in the film grain characteristics SEI message, the value of fg_colour_primaries is inferred to be equal to vui_colour_primaries.

fg_transfer_characteristics has the same semantics as specified in clause 7.3 for the vui_transfer_characteristics syntax element, except as follows:

– fg_transfer_characteristics specifies the transfer characteristics of the film grain characteristics specified in the SEI message, rather than the transfer characteristics used for the CLVS.

– When fg_transfer_characteristics is not present in the film grain characteristics SEI message, the value of fg_transfer_characteristics is inferred to be equal to vui_transfer_characteristics.

fg_matrix_coeffs has the same semantics as specified in clause 7.3 for the vui_matrix_coeffs syntax element, except as follows:

– fg_matrix_coeffs specifies the matrix coefficients of the film grain characteristics specified in the SEI message, rather than the matrix coefficients used for the CLVS.

– When fg_matrix_coeffs is not present in the film grain characteristics SEI message, the value of fg_matrix_coeffs is inferred to be equal to vui_matrix_coeffs.

– The values allowed for fg_matrix_coeffs are not constrained by the chroma format of the decoded video pictures that is indicated by the value of ChromaFormatIdc for the semantics of the VUI parameters.

fg_blending_mode_id identifies the blending mode used to blend the simulated film grain with the input images as specified in Table 6. fg_blending_mode_id shall be in the range of 0 to 1, inclusive. The values of 2 and 3 for fg_blending_mode_id 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 ignore film grain characteristic SEI messages with fg_blending_mode_id equal to 2 or 3.

Table 6 – fg_blending_mode_id values

Value	Description
0	Additive
1	Multiplicative

Depending on the value of fg_blending_mode_id, the blending mode is specified as follows:

– If fg_blending_mode_id is equal to 0, the blending mode is additive as specified by:

$$I_{grain}[\ c\ ][\ x\ ][\ y\ ] = \mathrm{Clip3}(\ 0,\ (\ 1 \ll \mathrm{fgBitDepth}[\ c\ ]\ ) - 1,\ \hat{I}[\ c\ ][\ x\ ][\ y\ ] + G[\ c\ ][\ x\ ][\ y\ ]\ ) \quad (18)$$

– Otherwise (fg_blending_mode_id is equal to 1), the blending mode is multiplicative as specified by:

$$\begin{aligned} I_{grain}[\ c\ ][\ x\ ][\ y\ ] = \mathrm{Clip3}(\ 0,\ (\ 1 \ll \mathrm{fgBitDepth}[\ c\ ]\ ) - 1,\ \hat{I}[\ c\ ][\ x\ ][\ y\ ] + \\ \mathrm{Round}(\ (\ \hat{I}[\ c\ ][\ x\ ][\ y\ ] * G[\ c\ ][\ x\ ][\ y\ ]\ ) \div (\ (\ 1 \ll \mathrm{fgBitDepth}[\ c\ ]\ ) - 1\ )\ )\ ) \end{aligned} \quad (19)$$

where Î[c][x][y] represents the sample value at coordinates x, y of the colour component c of the input image Î, G[c][x][y] is the simulated film grain value at the same position and colour component, and fgBitDepth[c] is the number of bits used for each sample in a fixed-length unsigned binary representation of the arrays I_{grain}[c][x][y], Î[c][x][y], and G[c][x][y], where c = 0..2, x = 0..PicWidthInLumaSamples − 1, and y = 0..PicHeightInLumaSamples − 1.

fg_log2_scale_factor specifies a scale factor used in the film grain characterization equations.

fg_comp_model_present_flag[c] equal to 0 indicates that film grain is not modelled on the c-th colour component, where c equal to 0 refers to the luma component, c equal to 1 refers to the Cb component, and c equal to 2 refers to the Cr component. fg_comp_model_present_flag[c] equal to 1 indicates that syntax elements specifying modelling of film grain on colour component c are present in the SEI message.

When fg_separate_colour_description_present_flag is equal to 0 and ChromaFormatIdc is equal to 0, the value of fg_comp_model_present_flag[1] and fg_comp_model_present_flag[2] shall be equal to 0.

fg_num_intensity_intervals_minus1[c] plus 1 specifies the number of intensity intervals for which a specific set of model values has been estimated.

NOTE 6 – The intensity intervals could overlap in order to simulate multi-generational film grain.

fg_num_model_values_minus1[c] plus 1 specifies the number of model values present for each intensity interval in which the film grain has been modelled. The value of fg_num_model_values_minus1[c] shall be in the range of 0 to 5, inclusive.

fg_intensity_interval_lower_bound[c][i] specifies the lower bound of the i-th intensity interval for which the set of model values applies.

fg_intensity_interval_upper_bound[c][i] specifies the upper bound of the i-th intensity interval for which the set of model values applies.

The variable intensityIntervalIdx[c][x][y][j] represents the j-th index to the list of intensity intervals selected for the sample value Î[c][x][y] for c = 0..2, x = 0..PicWidthInLumaSamples − 1, y = 0..PicHeightInLumaSamples − 1, and j = 0..numApplicableIntensityIntervals[c][x][y] − 1, where numApplicableIntensityIntervals[c][x][y] is derived below.

Depending on the value of fg_model_id, the selection of the one or more intensity intervals for the sample value Î[c][x][y] is specified as follows:

– The variable numApplicableIntensityIntervals[c][x][y] is initially set equal to 0.
– If fg_model_id is equal to 0, the following applies:
  – The top-left sample location (xB, yB) of the current 8x8 block b that contains the sample value Î[c][x][y] is derived as (xB, yB) = (x / 8, y / 8).
  – The average value b_{avg} of the current 8x8 block b is derived as follows:

```
sum8x8 = 0
for( i = 0; i < 8; i++ )
    for( j = 0; j < 8; j++ )
        sum8x8  +=  Î[ c ][ xB * 8 + i ][yB * 8 + j ]                                              (20)
bavg = Clip3( 0, 255, ( sum8x8 + ( 1 << ( fgBitDepth[ c ] − 3 ) ) ) >> ( fgBitDepth[ c ] − 2 ) )
```

  – The value of intensityIntervalIdx[c][x][y][j] is derived as follows:

```
for( i = 0, j = 0; i <= fg_num_intensity_intervals_minus1[ c ]; i++ )
    if( bavg >= fg_intensity_interval_lower_bound[ c ][ i ] &&
            bavg <= fg_intensity_interval_upper_bound[ c ][ i ] ) {
        intensityIntervalIdx[ c ][ x ][ y ][ j ] = i                                              (21)
        j++
    }
numApplicableIntensityIntervals[ c ][ x ][ y ] = j
```

– Otherwise (fg_model_id is equal to 1), the value of intensityIntervalIdx[c][x][y][j] is derived as follows:

```
I8[ c ][ x ][ y ] = ( fgBitDepth[ c ] = = 8 ) ? ( Î[ c ][ x ][ y ] :
        Clip3( 0, 255, ( Î[ c ][ x ][ y ] + ( 1 << ( fgBitDepth[ c ] − 9 ) ) ) >> ( fgBitDepth[ c ] − 8 ) )
for( i = 0, j = 0; i <= fg_num_intensity_intervals_minus1[ c ]; i++ )
    if( I8[ c ][ x ][ y ] >= fg_intensity_interval_lower_bound[ c ][ i ] &&                    (22)
            I8[ c ][ x ][ y ] <= fg_intensity_interval_upper_bound[ c ][ i ] ) {
        intensityIntervalIdx[ c ][ x ][ y ][ j ] = i
        j++
    }
numApplicableIntensityIntervals[ c ][ x ][ y ] = j
```

Samples that do not fall into any of the defined intervals (i.e., those samples for which the value of numApplicableIntensityIntervals[c][x][y] is equal to 0) are not modified by the grain generation function. Samples that fall into more than one interval (i.e., those samples for which the value of numApplicableIntensityIntervals[c][x][y] is greater than 1) will originate multi-generation grain. Multi-generation grain results from adding the grain computed independently for each of the applicable intensity intervals.

In the equations in the remainder of this clause, the variable s_j in each instance of the list fg_comp_model_value[c][s_j] is the value of intensityIntervalIdx[c][x][y][j] derived for the sample value Î[c][x][y].

fg_comp_model_value[c][i][j] specifies the j-th model value for the colour component c and the i-th intensity interval. The set of model values has different meaning depending on the value of fg_model_id.

The value of fg_comp_model_value[c][i][j] is constrained as follows, and could be additionally constrained as specified elsewhere in this clause:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][j] shall be in the range of 0 to $2^{\text{fgBitDepth}[c]} - 1$, inclusive.
– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][j] shall be in the range of $-2^{(\text{fgBitDepth}[c] - 1)}$ to $2^{(\text{fgBitDepth}[c] - 1)} - 1$, inclusive.

Depending on the value of fg_model_id, the synthesis of the film grain is modelled as follows:

– If fg_model_id is equal to 0, a frequency filtering model enables simulating the original film grain for c = 0..2, x = 0..PicWidthInLumaSamples − 1, and y = 0..PicHeightInLumaSamples − 1 as specified by:

$$G[\,c\,][\,x\,][\,y\,] = (\,\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,0\,] * Q[\,c\,][\,x\,][\,y\,] + \text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,5\,] * G[\,c-1\,][\,x\,][\,y\,]\,) \gg \text{fg\_log2\_scale\_factor} \quad (23)$$

where Q[c] is a two-dimensional random process generated by filtering 16x16 blocks gaussRv with random-value elements gaussRv_{ij} generated with a normalized Gaussian distribution (independent and identically distributed Gaussian random variable samples with zero mean and unity variance) and where the value of an element G[c − 1][x][y] used in the right-hand side of the equation is inferred to be equal to 0 when c − 1 is less than 0.

NOTE 7 – A normalized Gaussian random variable can be generated from two independent, uniformly distributed random values over the interval from 0 to 1 (and not equal to 0), denoted as uRv_0 and uRv_1, using the Box-Muller transformation specified by:

$$\text{gaussRv}_{i,j} = \text{Sqrt}(\,-2 * \text{Ln}(\,\text{uRv}_0\,)\,) * \text{Cos}(\,2 * \pi * \text{uRv}_1\,) \quad (24)$$

where π is Archimedes' constant 3.141 592 653 589 793....

The band-pass filtering of blocks gaussRv can be performed in the discrete cosine transform (DCT) domain as follows:

```
for( y = 0; y < 16; y++ )
    for( x = 0; x < 16; x++ )
        if( ( x < fg_comp_model_value[ c ][ sj ][ 3 ]  &&  y < fg_comp_model_value[ c ][ sj ][ 4 ] )  ||      (25)
             x > fg_comp_model_value[ c ][ sj ][ 1 ]  ||  y > fg_comp_model_value[ c ][ sj ][ 2 ] )
            gaussRv[ x ][ y ] = 0
filteredRv = IDCT16x16( gaussRv )
```

where IDCT16x16(z) refers to a unitary inverse discrete cosine transformation (IDCT) operating on a 16x16 matrix argument z as specified by:

$$\text{IDCT16x16}(\,z\,) = r * z * r^T \quad (26)$$

where the superscript T indicates a matrix transposition and r is the 16x16 matrix with elements r_{ij} specified by:

$$r_{i,j} = \frac{(\,(\,i == 0\,)\,?\,1 : \text{Sqrt}(\,2\,)\,)}{4} * \text{Cos}\left(\frac{i * (\,2 * j + 1\,) * \pi}{32}\right) \quad (27)$$

where π is Archimedes' constant 3.141 592 653 589 793....

Q[c] is formed by the frequency-filtered blocks filteredRv.

NOTE 8 – Coded model values are based on blocks of size 16x16, but a decoder implementation could use other block sizes. For example, decoders implementing the IDCT on 8x8 blocks could down-convert by a factor of two the set of coded model values fg_comp_model_value[c][s_j][i] for i equal to 1..4.

NOTE 9 – To reduce the degree of visible blocks that result from mosaicking the frequency-filtered blocks filteredRv, decoders could apply a low-pass filter to the boundaries between frequency-filtered blocks.

– Otherwise (fg_model_id is equal to 1), an auto-regression model enables simulating the original film grain for c = 0..2, x = 0..PicWidthInLumaSamples − 1, and y = 0..PicHeightInLumaSamples − 1 as specified by:

$$\begin{aligned} G[\,c\,][\,x\,][\,y\,] = (\,&\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,0\,] * n[\,c\,][\,x][\,y\,] + \\ &\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,1\,] * (\,G[\,c\,][\,x-1\,][\,y\,] + \\ &(\,(\,\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,4\,] * G[\,c\,][\,x\,][\,y-1\,]\,) \gg \\ &\text{fg\_log2\_scale\_factor}\,)\,) + \text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,3\,] * \\ &(\,(\,(\,\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,4\,] * G[\,c\,][\,x-1\,][\,y-1\,]\,) \gg \\ &\text{fg\_log2\_scale\_factor}\,) + G[\,c\,][\,x+1\,][\,y-1\,]\,) + \\ &\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,5\,] * (\,G[\,c\,][\,x-2\,][\,y\,] + \\ &(\,(\,\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,4\,] * \text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,4\,] * G[\,c\,][\,x\,][\,y-2\,]\,) \gg \\ &(\,2 * \text{fg\_log2\_scale\_factor}\,)\,)\,) + \\ &\text{fg\_comp\_model\_value}[\,c\,][\,s_j\,][\,2\,] * G[\,c-1\,][\,x\,][\,y\,]\,) \gg \text{fg\_log2\_scale\_factor} \end{aligned} \quad (28)$$

where n[c][x][y] is a random value with normalized Gaussian distribution (independent and identically distributed Gaussian random variable samples with zero mean and unity variance for each value of c, x, and y) and the value of an element G[c][x][y] used in the right-hand side of the equation is inferred to be equal to 0 when any of the following conditions are true:

– c is less than 0,

– x is less than 0,

– y is less than 0.

fg_comp_model_value[c][i][0] provides the first model value for the model as specified by fg_model_id. fg_comp_model_value[c][i][0] corresponds to the standard deviation of the Gaussian noise term in the generation functions specified in Equations 23 through 28.

fg_comp_model_value[c][i][1] provides the second model value for the model as specified by fg_model_id. When fg_model_id is equal to 0, fg_comp_model_value[c][i][1] shall be greater than or equal to 0 and less than 16.

When not present in the film grain characteristics SEI message, fg_comp_model_value[c][i][1] is inferred as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][1] is inferred to be equal to 8.

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][1] is inferred to be equal to 0.

fg_comp_model_value[c][i][1] is interpreted as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][1] indicates the horizontal high cut frequency to be used to filter the DCT of a block of 16x16 random values.

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][1] indicates the first order spatial correlation for neighbouring samples (x − 1, y) and (x, y − 1).

fg_comp_model_value[c][i][2] provides the third model value for the model as specified by fg_model_id. When fg_model_id is equal to 0, fg_comp_model_value[c][i][2] shall be greater than or equal to 0 and less than 16.

When not present in the film grain characteristics SEI message, fg_comp_model_value[c][i][2] is inferred as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][2] is inferred to be equal to fg_comp_model_value[c][i][1]

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][2] is inferred to be equal to 0.

fg_comp_model_value[c][i][2] is interpreted as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][2] indicates the vertical high cut frequency to be used to filter the DCT of a block of 16x16 random values.

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][2] indicates the colour correlation between consecutive colour components.

fg_comp_model_value[c][i][3] provides the fourth model value for the model as specified by fg_model_id. When fg_model_id is equal to 0, fg_comp_model_value[c][i][3] shall be greater than or equal to 0 and less than or equal to fg_comp_model_value[c][i][1].

When not present in the film grain characteristics SEI message, fg_comp_model_value[c][i][3] is inferred to be equal to 0.

fg_comp_model_value[c][i][3] is interpreted as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][3] indicates the horizontal low cut frequency to be used to filter the DCT of a block of 16x16 random values.

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][3] indicates the first order spatial correlation for neighbouring samples (x − 1, y − 1) and (x + 1, y − 1).

fg_comp_model_value[c][i][4] provides the fifth model value for the model as specified by fg_model_id. When fg_model_id is equal to 0, fg_comp_model_value[c][i][4] shall be greater than or equal to 0 and less than or equal to fg_comp_model_value[c][i][2].

When not present in the film grain characteristics SEI message, fg_comp_model_value[c][i][4] is inferred to be equal to fg_model_id.

fg_comp_model_value[c][i][4] is interpreted as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][4] indicates the vertical low cut frequency to be used to filter the DCT of a block of 16x16 random values.

– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][4] indicates the aspect ratio of the modelled grain.

fg_comp_model_value[c][i][5] provides the sixth model value for the model as specified by fg_model_id.

When not present in the film grain characteristics SEI message, fg_comp_model_value[c][i][5] is inferred to be equal to 0.

fg_comp_model_value[c][i][5] is interpreted as follows:

– If fg_model_id is equal to 0, fg_comp_model_value[c][i][5] indicates the colour correlation between consecutive colour components.
– Otherwise (fg_model_id is equal to 1), fg_comp_model_value[c][i][5] indicates the second order spatial correlation for neighbouring samples (x, y − 2) and (x − 2, y).

fg_characteristics_persistence_flag specifies the persistence of the film grain characteristics SEI message for the current layer.

fg_characteristics_persistence_flag equal to 0 specifies that the film grain characteristics SEI message applies to the current decoded picture only.

fg_characteristics_persistence_flag equal to 1 specifies that the film grain characteristics SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.
– The bitstream ends.
– A picture in the current layer in an AU associated with a film grain characteristics SEI message is output that follows the current picture in output order.

8.6 Frame packing arrangement SEI message

8.6.1 Frame packing arrangement SEI message syntax

frame_packing_arrangement(payloadSize) {	**Descriptor**
fp_arrangement_id	ue(v)
fp_arrangement_cancel_flag	u(1)
if(!fp_arrangement_cancel_flag) {	
fp_arrangement_type	u(7)
fp_quincunx_sampling_flag	u(1)
fp_content_interpretation_type	u(6)
fp_spatial_flipping_flag	u(1)
fp_frame0_flipped_flag	u(1)
fp_field_views_flag	u(1)
fp_current_frame_is_frame0_flag	u(1)
fp_frame0_self_contained_flag	u(1)
fp_frame1_self_contained_flag	u(1)
if(!fp_quincunx_sampling_flag && fp_arrangement_type != 5) {	
fp_frame0_grid_position_x	u(4)
fp_frame0_grid_position_y	u(4)
fp_frame1_grid_position_x	u(4)
fp_frame1_grid_position_y	u(4)
}	
fp_arrangement_reserved_byte	u(8)
fp_arrangement_persistence_flag	u(1)
}	
fp_upsampled_aspect_ratio_flag	u(1)
}	

8.6.2 Frame packing arrangement SEI message semantics

This SEI message informs the decoder that the cropped decoded picture contains samples of multiple distinct spatially packed constituent frames that are packed into one frame, or that the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames, using an indicated frame packing arrangement scheme. This information can be used by the decoder to appropriately rearrange the samples and process the samples of the constituent frames appropriately for display or other purposes (which are outside the scope of this Specification).

This SEI message may be associated with pictures that are either frames or fields (as determined outside the scope of this Specification). The frame packing arrangement of the samples is specified in terms of the sampling structure of a frame in order to define a frame packing arrangement structure that is invariant with respect to whether a picture is a single field of such a packed frame or is a complete packed frame.

NOTE 1 – The interpretation of frame_packing_arrangement_type is in alignment with the code point specifications in Rec. ITU-T H.273 | ISO/IEC 23091-2. However, more values of frame_packing_arrangement_type are specified in Rec. ITU-T H.273 | ISO/IEC 23091-2 than are specified for use herein.

fp_arrangement_id contains an identifying number that may be used to identify the usage of the frame packing arrangement SEI message. The value of fp_arrangement_id shall be in the range of 0 to $2^{32} - 2$, inclusive.

Values of fp_arrangement_id from 0 to 255, inclusive, and from 512 to $2^{31} - 1$, inclusive, may be used as determined by the application. Values of fp_arrangement_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of fp_arrangement_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, shall ignore it.

fp_arrangement_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous frame packing arrangement SEI message in output order that applies to the current layer. fp_arrangement_cancel_flag equal to 0 indicates that frame packing arrangement information follows.

fp_arrangement_type identifies the indicated interpretation of the sample arrays of the output cropped decoded picture as specified in Table 7.

When fp_arrangement_type is equal to 3 or 4, each component plane of the output cropped decoded picture contains all samples (when ffi_field_pic_flag is equal to 0) or the samples corresponding to the top or bottom field (when ffi_field_pic_flag is equal to 1) of the samples of a frame packing arrangement structure.

Table 7 – Definition of fp_arrangement_type

Value	Interpretation
3	The frame packing arrangement structure contains a side-by-side packing arrangement of corresponding planes of two constituent frames as illustrated in Figure 6, Figure 7 and Figure 10.
4	The frame packing arrangement structure contains a top-bottom packing arrangement of corresponding planes of two constituent frames as illustrated in Figure 8 and Figure 9.
5	The component planes of the output cropped decoded pictures in output order form a temporal interleaving of alternating first and second constituent frames as illustrated in Figure 11.

NOTE 2 – Figure 6 to Figure 10 provide typical examples of rearrangement and upconversion processing for various packing arrangement schemes. Actual characteristics of the constituent frames are signalled in detail by the subsequent syntax elements of the frame packing arrangement SEI message. In Figure 6 to Figure 10, an 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 10 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 3 – When the output time of the samples of constituent frame 0 differs from the output time of the samples of constituent frame 1 (i.e., when fp_field_views_flag is equal to 1 or fp_arrangement_type is equal to 5) and the display system in use presents two views simultaneously, the display time for constituent frame 0 could be delayed to coincide with the display time for constituent frame 1. (The display process is not specified in this Specification.)

NOTE 4 – When fp_field_views_flag is equal to 1 or fp_arrangement_type is equal to 5, the value 0 for fixed_pic_rate_within_cvs_flag is not expected to be prevalent in industry use of this SEI message.

NOTE 5 – fp_arrangement_type equal to 5 describes a temporal interleaving process of different views.

All other values of fp_arrangement_type are reserved for future use by ITU-T | ISO/IEC. It is a requirement of bitstream conformance that bitstreams conforming to this version of this Specification shall not contain such other values of fp_arrangement_type. Decoders shall ignore frame packing arrangement SEI messages that contain reserved values of fp_arrangement_type.

fp_quincunx_sampling_flag equal to 1 indicates that each colour component plane of each constituent frame is quincunx sampled as illustrated in Figure 10 and fp_quincunx_sampling_flag equal to 0 indicates that the colour component planes of each constituent frame are not quincunx sampled.

When fp_arrangement_type is equal to 5, it is a requirement of bitstream conformance that fp_quincunx_sampling_flag shall be equal to 0.

NOTE 6 – For any chroma format (monochrome, 4:2:0, 4:2:2 or 4:4:4), the luma plane and each chroma plane (as applicable) is quincunx sampled as illustrated in Figure 10 when fp_quincunx_sampling_flag is equal to 1.

fp_content_interpretation_type indicates the intended interpretation of the constituent frames as specified in Table 8. Values of fp_content_interpretation_type that do not appear in Table 8 are reserved for future specification by ITU-T | ISO/IEC and shall not be present in bitstreams conforming to this version of this Specification. Decoders shall ignore frame packing arrangement SEI messages that contain reserved values of fp_content_interpretation_type.

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

Table 8 – Definition of fp_content_interpretation_type

Value	Interpretation
0	Unknown or 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 7 – The value 2 for fp_content_interpretation_type is not expected to be prevalent in industry use of this SEI message. However, the value was specified herein for purposes of completeness.

fp_spatial_flipping_flag equal to 1, when fp_arrangement_type is equal to 3 or 4, indicates that one of the two constituent frames is spatially flipped relative to its intended orientation for display or other such purposes.

When fp_arrangement_type is equal to 3 or 4 and fp_spatial_flipping_flag is equal to 1, the type of spatial flipping that is indicated is as follows:

– If fp_arrangement_type is equal to 3, the indicated spatial flipping is horizontal flipping.

– Otherwise (fp_arrangement_type is equal to 4), the indicated spatial flipping is vertical flipping.

When fp_arrangement_type is not equal to 3 or 4, it is a requirement of bitstream conformance that fp_spatial_flipping_flag shall be equal to 0. When fp_arrangement_type is not equal to 3 or 4, the value 1 for fp_spatial_flipping_flag is reserved for future use by ITU-T | ISO/IEC. When fp_arrangement_type is not equal to 3 or 4, decoders shall ignore the value 1 for fp_spatial_flipping_flag.

fp_frame0_flipped_flag, when fp_spatial_flipping_flag is equal to 1, indicates which one of the two constituent frames is flipped.

When fp_spatial_flipping_flag is equal to 1, fp_frame0_flipped_flag equal to 0 indicates that frame 0 is not spatially flipped and frame 1 is spatially flipped and fp_frame0_flipped_flag equal to 1 indicates that frame 0 is spatially flipped and frame 1 is not spatially flipped.

When fp_spatial_flipping_flag is equal to 0, it is a requirement of bitstream conformance that fp_frame0_flipped_flag shall be equal to 0. When fp_spatial_flipping_flag is equal to 0, the value 1 for fp_spatial_flipping_flag is reserved for future use by ITU-T | ISO/IEC. When fp_spatial_flipping_flag is equal to 0, decoders shall ignore the value of fp_frame0_flipped_flag.

fp_field_views_flag equal to 1 indicates that all pictures in the current CLVS are coded as fields, all fields of a particular parity are considered a first constituent frame and all fields of the opposite parity are considered a second constituent frame. It is a requirement of bitstream conformance that the fp_field_views_flag shall be equal to 0, the value 1 for fp_field_views_flag is reserved for future use by ITU-T | ISO/IEC and decoders shall ignore the value of fp_field_views_flag.

fp_current_frame_is_frame0_flag equal to 1, when fp_arrangement is equal to 5, indicates that the current decoded frame is constituent frame 0 and the next decoded frame in output order is constituent frame 1 and the display time of the constituent frame 0 should be delayed to coincide with the display time of constituent frame 1. fp_current_frame_is_frame0_flag equal to 0, when fp_arrangement is equal to 5, indicates that the current decoded frame is constituent frame 1 and the previous decoded frame in output order is constituent frame 0 and the display time of the constituent frame 1 should not be delayed for purposes of stereo-view pairing.

When fp_arrangement_type is not equal to 5, the constituent frame associated with the upper-left sample of the decoded frame is considered to be constituent frame 0 and the other constituent frame is considered to be constituent frame 1. When fp_arrangement_type is not equal to 5, it is a requirement of bitstream conformance that fp_current_frame_is_frame0_flag shall be equal to 0. When fp_arrangement_type is not equal to 5, the value 1 for fp_current_frame_is_frame0_flag is reserved for future use by ITU-T | ISO/IEC. When fp_arrangement_type is not equal to 5, decoders shall ignore the value of fp_current_frame_is_frame0_flag.

fp_frame0_self_contained_flag equal to 1 indicates that no inter prediction operations within the decoding process for the samples of constituent frame 0 of the CLVS refer to samples of any constituent frame 1. fp_frame0_self_contained_flag equal to 0 indicates that some inter prediction operations within the decoding process for the samples of constituent frame 0 of the CLVS might or might not refer to samples of some constituent frame 1. Within a CLVS, the value of fp_frame0_self_contained_flag in all frame packing arrangement SEI messages shall be the same.

fp_frame1_self_contained_flag equal to 1 indicates that no inter prediction operations within the decoding process for the samples of constituent frame 1 of the CLVS refer to samples of any constituent frame 0. fp_frame1_self_contained_flag equal to 0 indicates that some inter prediction operations within the decoding process for the samples of constituent frame 1 of the CLVS might or might not refer to samples of some constituent frame 0. Within a CLVS, the value of fp_frame1_self_contained_flag in all frame packing arrangement SEI messages shall be the same.

When fp_quincunx_sampling_flag is equal to 0 and fp_arrangement_type is not equal to 5, two (x, y) coordinate pairs are specified to determine the indicated luma sampling grid alignment for constituent frame 0 and constituent frame 1, relative to the upper left corner of the rectangular area represented by the samples of the corresponding constituent frame.

NOTE 8 – The location of chroma samples relative to luma samples could be indicated by the vui_chroma_sample_loc_type_frame or vui_chroma_sample_loc_type_top_field and vui_chroma_sample_loc_type_bottom_field syntax elements in the VUI parameters, when present.

fp_frame0_grid_position_x (when present) specifies the x component of the (x, y) coordinate pair for constituent frame 0.

fp_frame0_grid_position_y (when present) specifies the y component of the (x, y) coordinate pair for constituent frame 0.

fp_frame1_grid_position_x (when present) specifies the x component of the (x, y) coordinate pair for constituent frame 1.

fp_frame1_grid_position_y (when present) specifies the y component of the (x, y) coordinate pair for constituent frame 1.

When fp_quincunx_sampling_flag is equal to 0 and fp_arrangement_type is not equal to 5 the (x, y) coordinate pair for each constituent frame is interpreted as follows:

– If the (x, y) coordinate pair for a constituent frame is equal to (0, 0), this indicates a default sampling grid alignment specified as follows:
  – If fp_arrangement_type is equal to 3, the indicated position is the same as for the (x, y) coordinate pair value (4, 8), as illustrated in Figure 6.
  – Otherwise (fp_arrangement_type is equal to 4), the indicated position is the same as for the (x, y) coordinate pair value (8, 4), as illustrated in Figure 8.
– Otherwise, if the (x, y) coordinate pair for a constituent frame is equal to (15, 15), this indicates that the sampling grid alignment is unknown or unspecified or specified by other means not specified in this Specification.
– Otherwise, the x and y elements of the (x, y) coordinate pair specify the indicated horizontal and vertical sampling grid alignment positioning to the right of and below the upper left corner of the rectangular area represented by the corresponding constituent frame, respectively, in units of one sixteenth of the luma sample grid spacing between the samples of the columns and rows of the constituent frame that are present in the decoded frame (prior to any upsampling for display or other purposes).

NOTE 9 – The spatial location reference information fp_frame0_grid_position_x, fp_frame0_grid_position_y, fp_frame1_grid_position_x, and fp_frame1_grid_position_y is not provided when fp_quincunx_sampling_flag is equal to 1 because the spatial alignment in this case is assumed to be such that constituent frame 0 and constituent frame 1 cover corresponding spatial areas with interleaved quincunx sampling patterns as illustrated in Figure 10.

fp_arrangement_reserved_byte is reserved for future use by ITU-T | ISO/IEC. It is a requirement of bitstream conformance that the value of fp_arrangement_reserved_byte shall be equal to 0. All other values of fp_arrangement_reserved_byte are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of fp_arrangement_reserved_byte.

fp_arrangement_persistence_flag specifies the persistence of the frame packing arrangement SEI message for the current layer.

fp_arrangement_persistence_flag equal to 0 specifies that the frame packing arrangement SEI message applies to the current decoded frame only.

fp_arrangement_persistence_flag equal to 1 specifies that the frame packing arrangement SEI message applies to the current decoded picture and persists all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a frame packing arrangement SEI message is output that follows the current picture in output order.

fp_upsampled_aspect_ratio_flag equal to 1 indicates that the SAR indicated by the VUI parameters or the SARI SEI message identifies the SAR of the samples after the application of an upconversion process to produce a higher resolution frame from each constituent frame as illustrated in Figure 6 to Figure 10. fp_upsampled_aspect_ratio_flag equal to 0 indicates that the SAR indicated by the VUI parameters or the SARI SEI message identifies the SAR of the samples before the application of any such upconversion process.

NOTE 10 – The SAR indicated in the VUI parameters or the SARI SEI message could indicate the preferred display picture shape for the packed decoded frame output by a decoder that does not interpret the frame packing arrangement SEI message. When fp_upsampled_aspect_ratio_flag is equal to 1, the SAR produced in each up-converted colour plane is indicated to be the same as the SAR indicated in the VUI parameters or the SARI SEI message in the examples shown in Figure 6 to Figure 10. When fp_upsampled_aspect_ratio_flag is equal to 0, the SAR produced in each colour plane prior to upconversion is indicated to be the same as the SAR indicated in the VUI parameters or the SARI SEI message in the examples shown in Figure 6 to Figure 10.

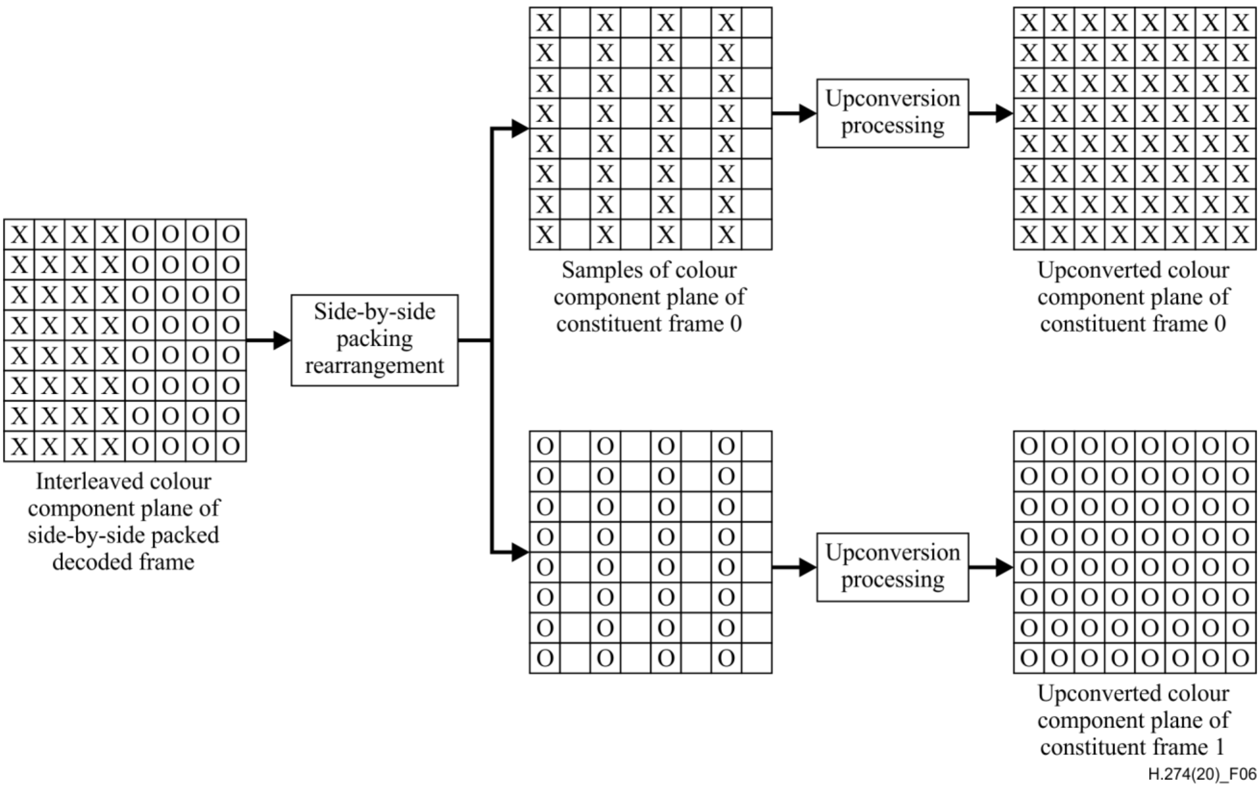


Figure 6 – Flowchart for rearrangement and upconversion of side-by-side packing arrangement with fp_arrangement_type equal to 3, fp_quincunx_sampling_flag equal to 0 and (x, y) equal to (0, 0) or (4, 8) for both constituent frames

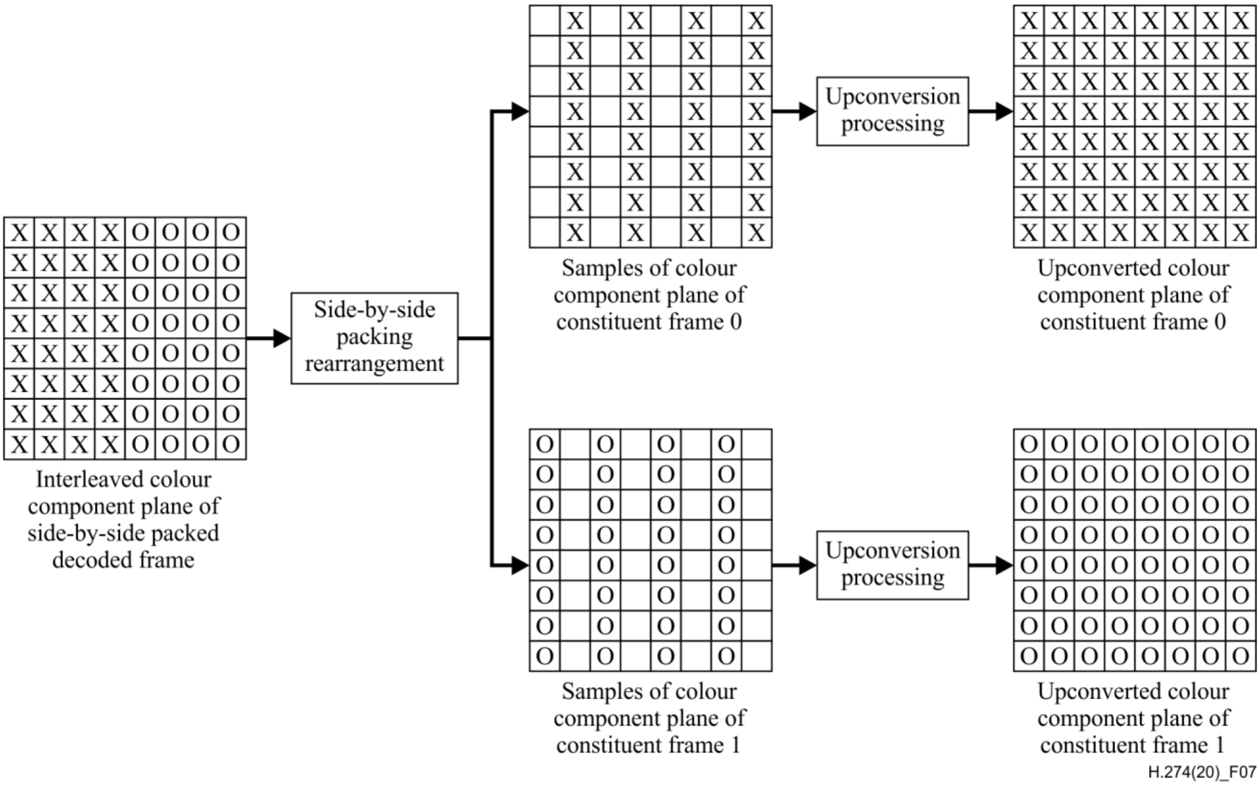


Figure 7 – Flowchart for rearrangement and upconversion of side-by-side packing arrangement with fp_arrangement_type equal to 3, fp_quincunx_sampling_flag equal to 0, (x, y) equal to (12, 8) for constituent frame 0 and (x, y) equal to (0, 0) or (4, 8) for constituent frame 1

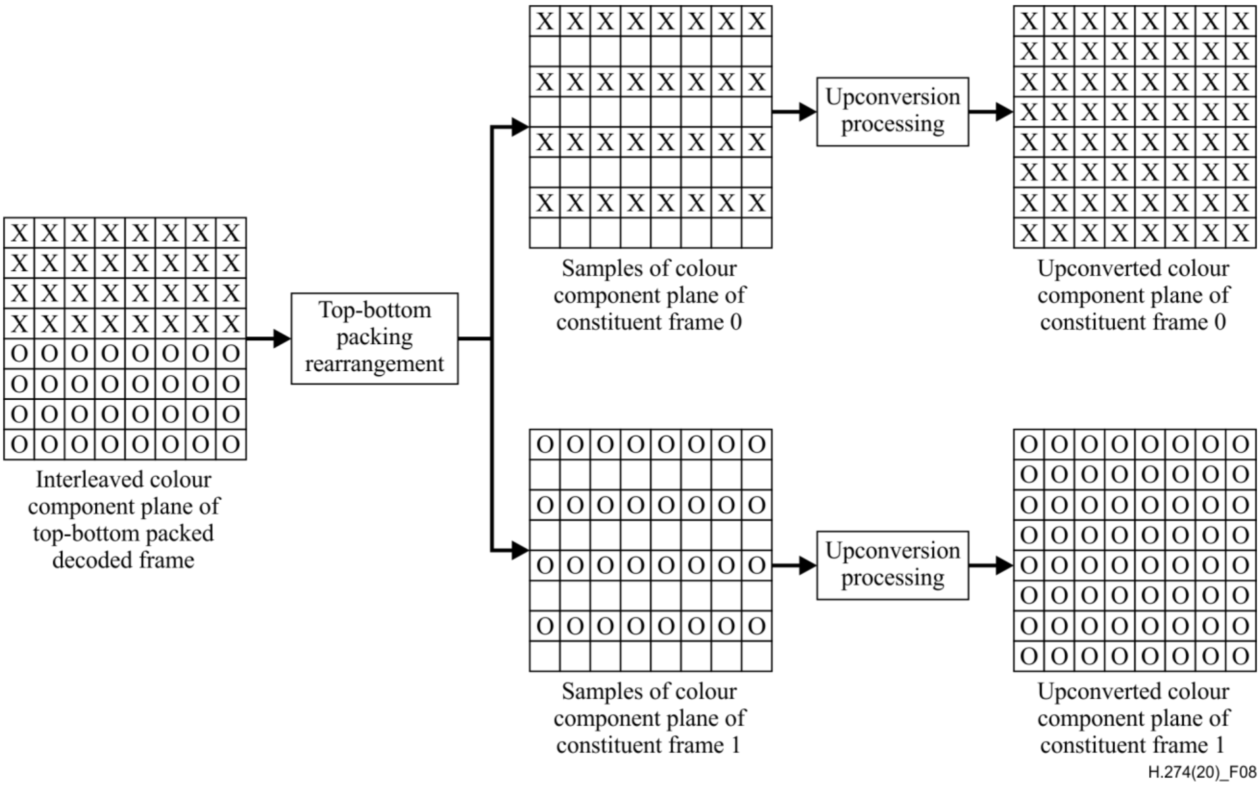


Figure 8 – Flowchart for rearrangement and upconversion of top-bottom packing arrangement with fp_arrangement_type equal to 4, fp_quincunx_sampling_flag equal to 0 and (x, y) equal to (0, 0) or (8, 4) for both constituent frames

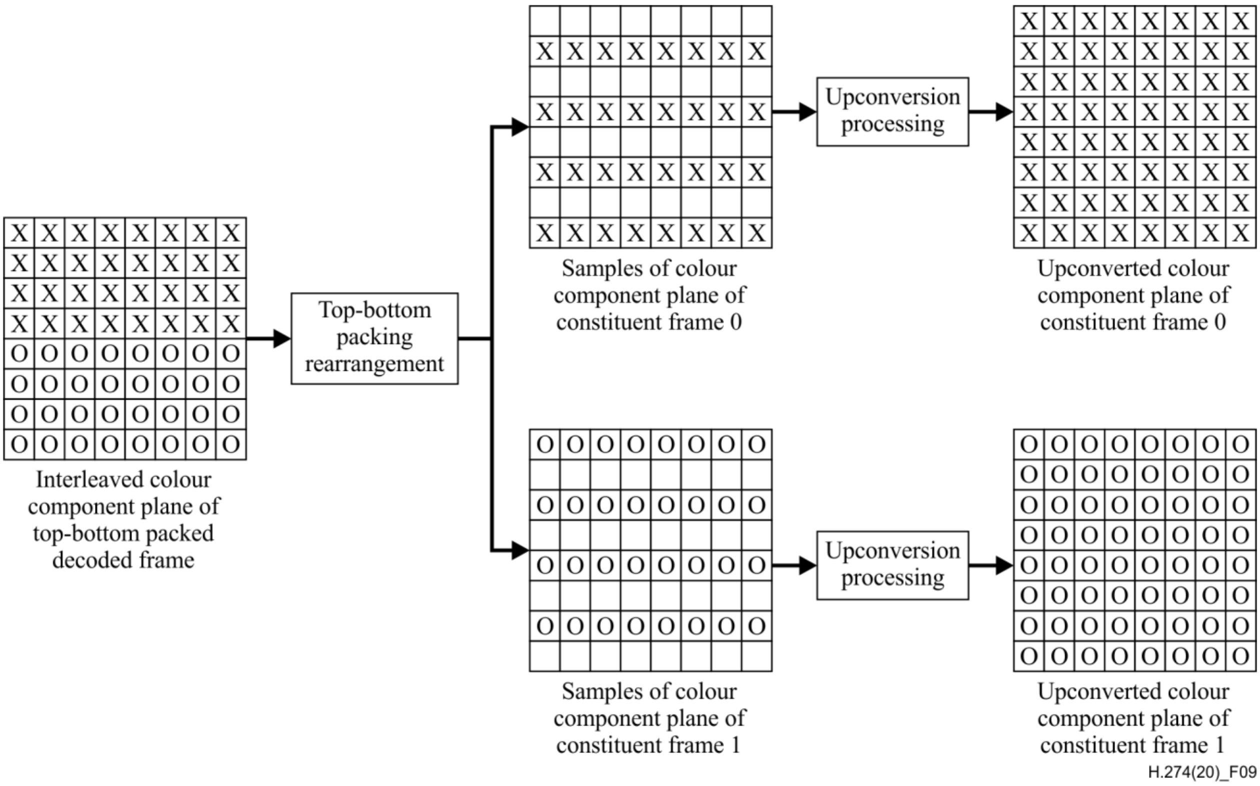


Figure 9 – Flowchart for rearrangement and upconversion of top-bottom packing arrangement with fp_arrangement_type equal to 4, fp_quincunx_sampling_flag equal to 0, (x, y) equal to (8, 12) for constituent frame 0 and (x, y) equal to (0, 0) or (8, 4) for constituent frame 1

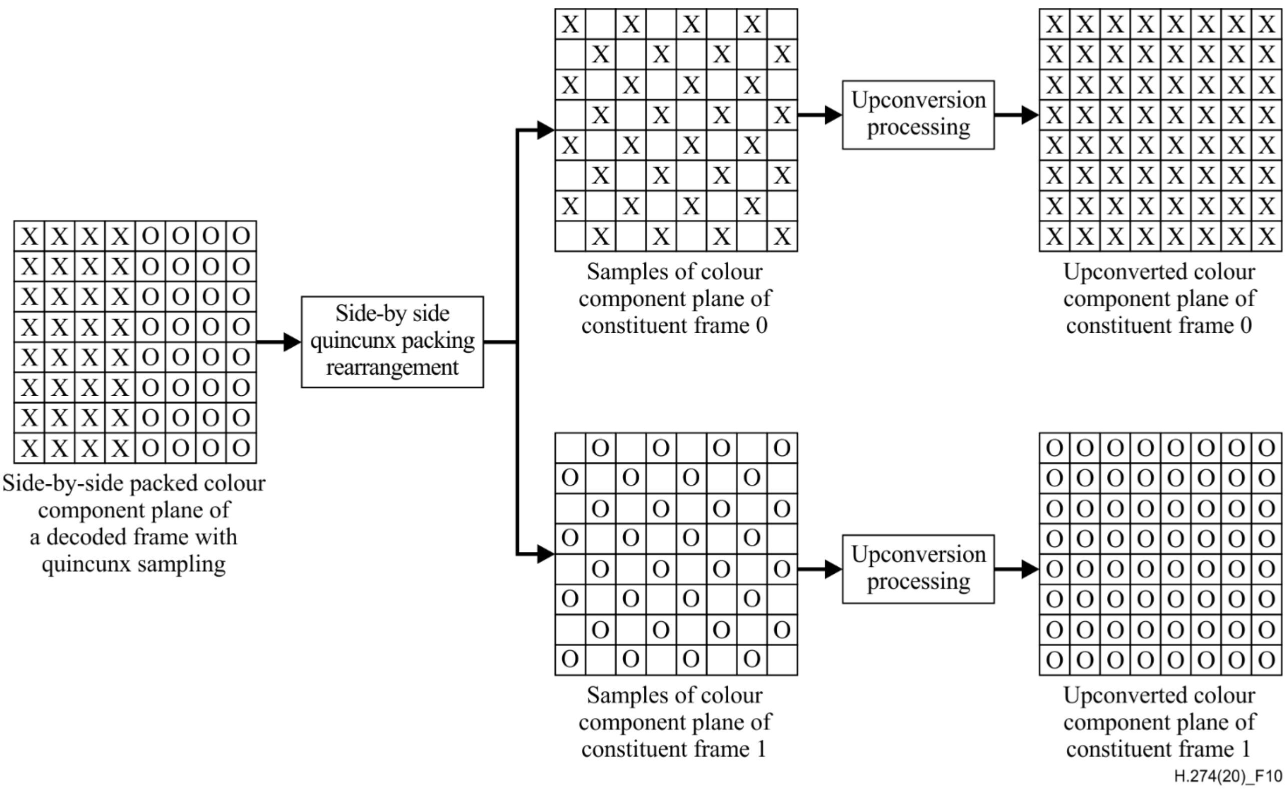


Figure 10 – Flowchart for rearrangement and upconversion of side-by-side packing arrangement with quincunx sampling (fp_arrangement_type equal to 3 with fp_quincunx_sampling_flag equal to 1)

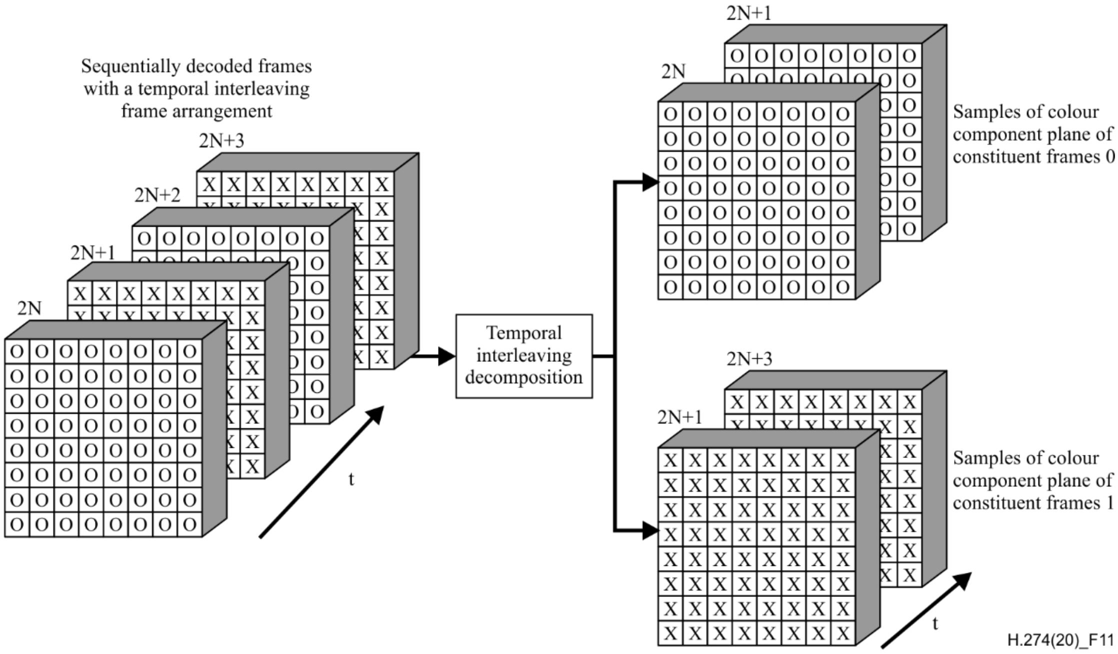


Figure 11 – Flowchart for rearrangement of a temporal interleaving frame arrangement (fp_arrangement_type equal to 5)

8.7 Parameter sets inclusion indication SEI message

8.7.1 Parameter sets inclusion indication SEI message syntax

parameter_sets_inclusion_indication(payloadSize) {	**Descriptor**
psii_self_contained_clvs_flag	u(1)
}	

8.7.2 Parameter sets inclusion indication SEI message semantics

This message provides an indication of whether the CLVS contains all the required NAL units for decoding the CLVS that is associated with the SEI message and whether temporal sublayer up-switching within the CLVS works without a need of fetching parameter sets from PUs earlier in decoding order than the PU containing the picture at which the temporal sublayer up-switching occurs. When the CLVS does not contain all the required NAL units, the NAL units that are not present in the CLVS may be provided externally.

psii_self_contained_clvs_flag equal to 1 indicates that the following restrictions apply:

– Each parameter set that is (directly or indirectly) referenced by any VCL NAL unit of the CLVS that is not a VCL NAL unit of a RASL picture (when present) associated with the first AU of the CLVS is present within the CLVS at a position that precedes, in decoding order, any NAL unit that (directly or indirectly) references the parameter set.
– For any STSA picture stsaPicA with temporal sublayer identifier equal to tIdA in the CLVS, the following applies:
  – stsaPicA does not refer to a PPS or an APS that precedes the first NAL unit of the PU containing stsaPicA in decoding order and has temporal sublayer identifier equal to tIdA.
  – For any picture picB with temporal sublayer identifier equal to tIdA and following stsaPicA in decoding order, picB does not refer to a PPS or an APS that has temporal sublayer identifier equal to tIdA that precedes the first NAL unit of the PU containing stsaPicA in decoding order.

psii_self_contained_clvs_flag equal to 0 indicates that this property might or might not apply.

8.8 Decoded picture hash SEI message

8.8.1 Decoded picture hash SEI message syntax

decoded_picture_hash(payloadSize) {	**Descriptor**
dph_sei_hash_type	u(8)
dph_sei_single_component_flag	u(1)
dph_sei_reserved_zero_7bits	u(7)
for(cIdx = 0; cIdx < (dph_sei_single_component_flag ? 1 : 3); cIdx++)	
if(dph_sei_hash_type = = 0)	
for(i = 0; i < 16; i++)	
dph_sei_picture_md5[cIdx][i]	b(8)
else if(dph_sei_hash_type = = 1)	
dph_sei_picture_crc[cIdx]	u(16)
else if(dph_sei_hash_type = = 2)	
dph_sei_picture_checksum[cIdx]	u(32)
}	

8.8.2 Decoded picture hash SEI message semantics

This message provides a hash for each colour component of the current decoded picture.

Use of this SEI message requires the definition of the following variables:

– A picture width and picture height in units of luma samples, denoted herein by PicWidthInLumaSamples and PicHeightInLumaSamples, respectively.
– A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.
– A bit depth for the samples of the luma component, denoted herein by $BitDepth_Y$, and when ChromaFormatIdc is not equal to 0, a bit depth for the samples of the two associated chroma components, denoted herein by $BitDepth_C$.
– For each colour component cIdx, an array of samples ComponentSample[cIdx][x][y].

The variables SubWidthC and SubHeightC are derived from ChromaFormatIdc as specified by Table 2.

Prior to computing the hash, the decoded picture data are arranged into one or three strings of bytes called pictureData[cIdx] of lengths dataLen[cIdx] as follows:

```
for( cIdx = 0; cIdx < dph_sei_single_component_flag ? 1 : 3; cIdx++ ) {
    if( cIdx  = =  0 ) {
        compWidth[ cIdx ] = PicWidthInLumaSamples
        compHeight[ cIdx ] = PicHeightInLumaSamples
        compDepth[ cIdx ] = BitDepthY
    } else {
        compWidth[ cIdx ] = PicWidthInLumaSamples / SubWidthC
        compHeight[ cIdx ] = PicHeightInLumaSamples / SubHeightC
        compDepth[ cIdx ] = BitDepthC                                          (29)
    }
    iLen = 0
    for( y = 0; y < compHeight[ cIdx ]; y++ ) /* raster scan order */
        for( x = 0; x < compWidth[ cIdx ]; x++) {
            pictureData[ cIdx ][ iLen++ ] = ComponentSample[ cIdx ][ x ][ y ] & 0xFF
            if( compDepth[ cIdx ] > 8 )
                pictureData[ cIdx ][ iLen++ ] = ComponentSample[ cIdx ][ x ][ y ]  >>  8
        }
    dataLen[ cIdx ] = iLen
}
```

where ComponentSample[cIdx] is a 2-dimension array of the decoded sample values of a component of a decoded picture.

dph_sei_hash_type indicates the method used to calculate the checksum as specified in Table 9 . Values of dph_sei_hash_type that are not listed in in Table 9 are reserved for future use by ITU-T | ISO/IEC and shall not be present in payload data conforming to this version of this Specification. Decoders shall ignore decoded picture hash SEI messages that contain reserved values of dph_sei_hash_type.

Table 9 – Interpretation of dph_sei_hash_type

dph_sei_hash_type	Method
0	MD5 (IETF RFC 1321)
1	CRC
2	Checksum

dph_sei_single_component_flag equal to 1 specifies that the picture associated with the decoded picture hash SEI message contains a single colour component. dph_sei_single_component_flag equal to 0 specifies that the picture associated with the decoded picture hash SEI message contains three colour components. The value of dph_sei_single_component_flag shall be equal to (ChromaFormatIdc = = 0).

dph_sei_reserved_zero_7bits shall be equal to 0. Values greater than 0 for dph_sei_reserved_zero_7bits are reserved for future use by ITU-T | ISO/IEC and shall not be present in payload data conforming to this version of this Specification. Decoders conforming to this version of this Specification shall ignore the value of dph_sei_reserved_zero_7bits.

dph_sei_picture_md5[cIdx][i] is the 16-byte MD5 hash of the cIdx-th colour component of the decoded picture. The value of dph_sei_picture_md5[cIdx][i] shall be equal to the value of digestVal[cIdx] obtained as follows, using the MD5 functions defined in IETF RFC 1321:

```
MD5Init( context )
MD5Update( context, pictureData[ cIdx ], dataLen[ cIdx ] )                    (30)
MD5Final( digestVal[ cIdx ], context )
```

dph_sei_picture_crc[cIdx] is the cyclic redundancy check (CRC) of the colour component cIdx of the decoded picture. The value of dph_sei_picture_crc[cIdx] shall be equal to the value of crcVal[cIdx] obtained as follows:

```
crc = 0xFFFF
pictureData[ cIdx ][ dataLen[ cIdx ] ] = 0
pictureData[ cIdx ][ dataLen[ cIdx ] + 1 ] = 0
for( bitIdx = 0; bitIdx < ( dataLen[ cIdx ] + 2 ) * 8; bitIdx++ ) {           (31)
  dataByte = pictureData[ cIdx ][ bitIdx >> 3 ]
  crcMsb = ( crc >> 15 ) & 1
  bitVal = ( dataByte >> ( 7 − ( bitIdx & 7 ) ) ) & 1
  crc = ( ( ( crc << 1 ) + bitVal ) & 0xFFFF ) ^ ( crcMsb * 0x1021 )
}
crcVal[ cIdx ] = crc
```

NOTE – The same CRC specification is found in Rec. ITU-T H.271.

dph_sei_picture_checksum[cIdx] is the checksum of the colour component cIdx of the decoded picture. The value of dph_sei_picture_checksum[cIdx] shall be equal to the value of checksumVal[cIdx] obtained as follows:

```
sum = 0
for( y = 0; y < compHeight[ cIdx ]; y++ )
  for( x = 0; x < compWidth[ cIdx ]; x++ ) {
    xorMask = ( x & 0xFF ) ^ ( y & 0xFF ) ^ ( x >> 8 ) ^ ( y >> 8 )
    sum = ( sum + ( ( ComponentSample[ cIdx ][ y * compWidth[ cIdx ] + x ] & 0xFF ) ^      (32)
        xorMask ) ) & 0xFFFFFFFF
    if( compDepth[ cIdx ] > 8 )
      sum = ( sum + ( ( ComponentSample[ cIdx ][ y * compWidth[ cIdx ] + x ] >> 8 ) ^
          xorMask ) ) & 0xFFFFFFFF
  }
checksumVal[ cIdx ] = sum
```

8.9 Mastering display colour volume SEI message

8.9.1 Mastering display colour volume SEI message syntax

mastering_display_colour_volume(payloadSize) {	**Descriptor**
for(c = 0; c < 3; c++) {	
mdcv_display_primaries_x[c]	u(16)
mdcv_display_primaries_y[c]	u(16)
}	
mdcv_white_point_x	u(16)
mdcv_white_point_y	u(16)
mdcv_max_display_mastering_luminance	u(32)
mdcv_min_display_mastering_luminance	u(32)
}	

8.9.2 Mastering display colour volume SEI message semantics

This SEI message identifies the colour volume (the colour primaries, white point, and luminance range) of a display considered to be the mastering display for the associated video content – e.g., the colour volume of a display that was used for viewing while authoring the video content. The described mastering display is a three-colour additive display system that has been configured to use the indicated mastering colour volume.

This SEI message does not identify the measurement methodologies and procedures used for determining the indicated values or provide any description of the mastering environment. It also does not provide information on colour transformations that would be appropriate to preserve creative intent on displays with colour volumes different from that of the described mastering display.

The information conveyed in this SEI message is intended to be adequate for purposes corresponding to the use of SMPTE ST 2086.

When a mastering display colour volume SEI message is present for any picture of a CLVS of a particular layer, a mastering display colour volume SEI message shall be present for the first picture of the CLVS. The mastering display colour volume SEI message persists for the current layer in decoding order from the current picture until the end of the CLVS. All mastering display colour volume SEI messages that apply to the same CLVS shall have the same content.

mdcv_display_primaries_x[c], when in the range of 5 to 37 000, inclusive, specifies the normalized x chromaticity coordinate of the colour primary component c of the mastering display, according to the CIE 1931 definition of x as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in increments of 0.00002. When mdcv_display_primaries_x[c] is not in the range of 5 to 37 000, inclusive, the normalized x chromaticity coordinate of the colour primary component c of the mastering display is unknown or unspecified or specified by other means not specified in this Specification.

mdcv_display_primaries_y[c], when in the range of 5 to 42 000, inclusive, specifies the normalized y chromaticity coordinate of the colour primary component c of the mastering display, according to the CIE 1931 definition of y as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in increments of 0.00002. When mdcv_display_primaries_y[c] is not in the range of 5 to 42 000, inclusive, the normalized y chromaticity coordinate of the colour primary component c of the mastering display is unknown or unspecified or specified by other means not specified in this Specification.

For describing mastering displays that use red, green, and blue colour primaries, it is suggested that index value c equal to 0 should correspond to the green primary, c equal to 1 should correspond to the blue primary, and c equal to 2 should correspond to the red colour primary specified in the VUI parameters.

mdcv_white_point_x, when in the range of 5 to 37 000, inclusive, specifies the normalized x chromaticity coordinate of the white point of the mastering display, according to the CIE 1931 definition of x as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in normalized increments of 0.00002. When mdcv_white_point_x is not in the range of 5 to 37 000, inclusive, the normalized x chromaticity coordinate of the white point of the mastering display is indicated to be unknown or unspecified or specified by other means not specified in this Specification.

mdcv_white_point_y, when in the range of 5 to 42 000, inclusive, specifies the normalized y chromaticity coordinate of the white point of the mastering display, according to the CIE 1931 definition of y as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in normalized increments of 0.00002. When mdcv_white_point_y is not in the range of 5 to 42 000, inclusive, the normalized y chromaticity coordinate of the white point of the mastering display is indicated to be unknown or unspecified or specified by other means not specified in this Specification.

NOTE 1 – SMPTE ST 2086 specifies that the normalized x and y chromaticity coordinate values for the mastering display colour primaries and white point are to be represented with four decimal places. This would correspond with using values of the syntax elements mdcv_display_primaries_x[c], mdcv_display_primaries_y[c], mdcv_white_point_x, and mdcv_white_point_y, as defined in this Specification, that are multiples of 5.

NOTE 2 – An example of the use of values outside the range for which semantics are specified in this Specification is that ANSI/CTA 861-G uses normalized (x, y) chromaticity coordinate values of (0,0) for the white point to indicate that the white point chromaticity is unknown.

mdcv_max_display_mastering_luminance, when in the range of 50 000 to 100 000 000, specifies the nominal maximum display luminance of the mastering display in units of 0.0001 candelas per square metre. When mdcv_max_display_mastering_luminance is not in the range of 50 000 to 100 000 000, the nominal maximum display luminance of the mastering display is indicated to be unknown or unspecified or specified by other means not specified in this Specification.

NOTE 3 – SMPTE ST 2086 specifies that the nominal maximum display luminance of the mastering display is to be specified as a multiple of 1 candela per square metre. This would correspond with using values of the syntax element mdcv_max_display_mastering_luminance, as defined in this Specification, that are a multiple of 10 000.

NOTE 4 – An example of the use of values outside the range for which semantics are specified in this Specification is that ANSI/CTA 861-G uses the value 0 for the nominal maximum display luminance of the mastering display to indicate that the nominal maximum display luminance of the mastering display is unknown.

mdcv_min_display_mastering_luminance, when in the range of 1 to 50 000, specifies the nominal minimum display luminance of the mastering display in units of 0.0001 candelas per square metre. When mdcv_min_display_mastering_luminance is not in the range of 1 to 50 000, the nominal maximum display luminance of the mastering display is unknown or unspecified or specified by other means not specified in this Specification. When mdcv_max_display_mastering_luminance is equal to 50 000, mdcv_min_display_mastering_luminance shall not be equal to 50 000.

NOTE 5 – SMPTE ST 2086 specifies that the nominal minimum display luminance of the mastering display is to be specified as a multiple of 0.0001 candelas per square metre, which corresponds to the semantics specified in this Specification.

NOTE 6 – An example of the use of values outside the range for which semantics are specified in this Specification is that ANSI/CTA 861-G uses the value 0 for the nominal minimum display luminance of the mastering display to indicate that the nominal minimum display luminance of the mastering display is unknown.

NOTE 7 – Another example of the potential use of values outside the range for which semantics are specified in this Specification is that SMPTE ST 2086 indicates that values outside the specified range could be used to indicate that the black level and contrast of the mastering display have been adjusted using picture line-up generation equipment (PLUGE).

At the minimum luminance, the mastering display is considered to have the same nominal chromaticity as the white point.

8.10 Content light level information SEI message

8.10.1 Content light level information SEI message syntax

content_light_level_info(payloadSize) {	**Descriptor**
clli_max_content_light_level	u(16)
clli_max_pic_average_light_level	u(16)
}	

8.10.2 Content light level information SEI message semantics

This SEI message identifies upper bounds for the nominal target brightness light level of the pictures of the CLVS.

The information conveyed in this SEI message is intended to be adequate for purposes corresponding to the use of the CEA 861.3 specification.

The semantics of the content light level information SEI message are defined in relation to the values of samples in a 4:4:4 representation of red, green, and blue colour primary intensities in the linear light domain for the pictures of the CLVS, in units of candelas per square metre. However, this SEI message does not, by itself, identify a conversion process for converting the sample values of a decoded picture to the samples in a 4:4:4 representation of red, green, and blue colour primary intensities in the linear light domain for the picture.

NOTE 1 – Other syntax elements, such as vui_colour_primaries, vui_transfer_characteristics, and vui_matrix_coeffs, when present, could assist in the identification of such a conversion process.

Given the red, green, and blue colour primary intensities in the linear light domain for the location of a luma sample in a corresponding 4:4:4 representation, denoted as E_R, E_G, and E_B, the maximum component intensity is defined as E_{Max} = Max(E_R, Max(E_G, E_B)). The light level corresponding to the stimulus is then defined as the CIE 1931 luminance corresponding to equal amplitudes of E_{Max} for all three colour primary intensities for red, green, and blue (with appropriate scaling to reflect the nominal luminance level associated with peak white – e.g., ordinarily scaling to associate peak white with 10 000 candelas per square metre when vui_transfer_characteristics is equal to 16).

NOTE 2 – Since the maximum value E_{Max} is used in this definition at each sample location, rather than a direct conversion from E_R, E_G, and E_B to the corresponding CIE 1931 luminance, the CIE 1931 luminance at a location could in some cases be less than the indicated light level. This situation would occur, for example, when E_R and E_G are very small and E_B is large, in which case the indicated light level would be much larger than the true CIE 1931 luminance associated with the (E_R, E_G, E_B) triplet.

All content light level information SEI messages that apply to the same CLVS shall have the same content.

clli_max_content_light_level, when not equal to 0, indicates an upper bound on the maximum light level among all individual samples in a 4:4:4 representation of red, green, and blue colour primary intensities (in the linear light domain) for the pictures of the CLVS, in units of candelas per square metre. When equal to 0, no such upper bound is indicated by clli_max_content_light_level.

clli_max_pic_average_light_level, when not equal to 0, indicates an upper bound on the maximum average light level among the samples in a 4:4:4 representation of red, green, and blue colour primary intensities (in the linear light domain) for any individual picture of the CLVS, in units of candelas per square metre. When equal to 0, no such upper bound is indicated by clli_max_pic_average_light_level.

When the visually relevant region does not correspond to the entire cropped decoded picture, such as for "letterbox" encoding of video content with a wide picture aspect ratio within a taller cropped decoded picture, the indicated average should be performed only within the visually relevant region.

8.11 Dependent random access point indication SEI message

8.11.1 Dependent random access point indication SEI message syntax

dependent_rap_indication(payloadSize) {	**Descriptor**
}	

8.11.2 Dependent random access point indication SEI message semantics

The picture associated with a dependent random access point (DRAP) indication SEI message is referred to as a DRAP picture.

The presence of the DRAP indication SEI message indicates that the constraints on picture order and picture referencing specified in this clause apply. These constraints can enable a decoder to properly decode the DRAP picture and the pictures that are in the same layer and follow it in both decoding order and output order without needing to decode any other pictures in the same layer except the associated IRAP picture of the DRAP picture.

The constraints indicated by the presence of the DRAP indication SEI message, which shall all apply, are as follows:

– The DRAP picture is a trailing picture.

– The DRAP picture has a temporal sublayer identifier equal to 0.

– The DRAP picture does not include any pictures in the same layer in the active entries of its reference picture lists except the associated IRAP picture of the DRAP picture.

– Any picture that is in the same layer and follows the DRAP picture in both decoding order and output order does not include, in the active entries of its reference picture lists, any picture that is in the same layer and precedes the DRAP picture in decoding order or output order, with the exception of the associated IRAP picture of the DRAP picture.

8.12 Alternative transfer characteristics information SEI message

8.12.1 Alternative transfer characteristics information SEI message syntax

alternative_transfer_characteristics (payloadSize) {	**Descriptor**
preferred_transfer_characteristics	u(8)
}	

8.12.2 Alternative transfer characteristics SEI message semantics

The alternative transfer characteristics SEI message provides a preferred alternative value for the transfer_characteristics syntax element that is indicated by the colour description syntax of the VUI parameters. This SEI message is intended to be used in cases when some value of vui_transfer_characteristics is preferred for interpretation of the pictures of the CLVS although some other value of vui_transfer_characteristics could also be acceptable for interpretation of the pictures of the CLVS and that other value is provided in the colour description syntax of the VUI parameters for interpretation by decoders that do not support interpretation of the preferred value (e.g., because the preferred value had not yet been defined in a previous version of this Specification).

When an alternative transfer characteristics SEI message is present for any picture of a CLVS of a particular layer and the first picture of the CLVS is an IRAP picture, an alternative transfer characteristics SEI message shall be present for that IRAP picture. The alternative transfer characteristics SEI message persists for the current layer in decoding order from the current picture until the end of the CLVS. All alternative transfer characteristics SEI messages that apply to the same CLVS shall have the same content.

preferred_transfer_characteristics specifies a preferred alternative value for the vui_transfer_characteristics syntax element of the colour description syntax of the VUI parameters. The semantics for preferred_transfer_characteristics are otherwise the same as for the vui_transfer_characteristics syntax element specified in the VUI parameters. When preferred_transfer_characteristics is not equal to the value of vui_transfer_characteristics indicated in the VUI parameters, decoders should ignore the value of vui_transfer_characteristics indicated in the VUI parameters and instead use the value indicated by preferred_transfer_characteristics.

8.13 Ambient viewing environment SEI message

8.13.1 Ambient viewing environment SEI message syntax

ambient_viewing_environment(payloadSize) {	**Descriptor**
ambient_illuminance	u(32)
ambient_light_x	u(16)
ambient_light_y	u(16)
}	

8.13.2 Ambient viewing environment SEI message semantics

The ambient viewing environment SEI message identifies the characteristics of the nominal ambient viewing environment for the display of the associated video content. The syntax elements of the ambient viewing environment SEI message can assist the receiving system in adapting the received video content for local display in viewing environments that could be similar or could substantially differ from those assumed or intended when mastering the video content.

This SEI message does not provide information on colour transformations that would be appropriate to preserve creative intent on displays with colour volumes different from that of the described mastering display.

When an ambient viewing environment SEI message is present for any picture of a CLVS of a particular layer and the first picture of the CLVS is an IRAP picture, an ambient viewing environment SEI message shall be present for that IRAP picture. The ambient viewing environment SEI message persists for the current layer in decoding order from the current picture until the end of the CLVS. All ambient viewing environment SEI messages that apply to the same CLVS shall have the same content.

ambient_illuminance specifies the environmental illuminance of the ambient viewing environment in units of 0.0001 lux. ambient_illuminance shall not be equal to 0.

ambient_light_x and **ambient_light_y** specify the normalized x and y chromaticity coordinates, respectively, of the environmental ambient light in the nominal viewing environment, according to the CIE 1931 definition of x and y as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in normalized increments of 0.00002. The values of ambient_light_x and ambient_light_y shall be in the range of 0 to 50 000.

NOTE – For example, the conditions identified in Rec. ITU-R BT.2035 could be expressed using ambient_illuminance equal to 100 000 with background chromaticity indicating D_{65} (ambient_light_x equal to 15 635, ambient_light_y equal to 16 450), or optionally in some regions, background chromaticity indicating D_{93} (ambient_light_x equal to 14 155, ambient_light_y equal to 14 855).

8.14 Content colour volume SEI message

8.14.1 Content colour volume SEI message syntax

content_colour_volume(payloadSize) {	**Descriptor**
ccv_cancel_flag	u(1)
if(!ccv_cancel_flag) {	
ccv_persistence_flag	u(1)
ccv_primaries_present_flag	u(1)
ccv_min_luminance_value_present_flag	u(1)
ccv_max_luminance_value_present_flag	u(1)
ccv_avg_luminance_value_present_flag	u(1)
ccv_reserved_zero_2bits	u(2)
if(ccv_primaries_present_flag)	
for(c = 0; c < 3; c++) {	
ccv_primaries_x[c]	i(32)
ccv_primaries_y[c]	i(32)
}	
if(ccv_min_luminance_value_present_flag)	
ccv_min_luminance_value	u(32)
if(ccv_max_luminance_value_present_flag)	
ccv_max_luminance_value	u(32)
if(ccv_avg_luminance_value_present_flag)	
ccv_avg_luminance_value	u(32)
}	
}	

8.14.2 Content colour volume SEI message semantics

The content colour volume SEI message describes the colour volume characteristics of the associated pictures. These colour volume characteristics are expressed in terms of a nominal range, although deviations from this range may occur.

The variable transferCharacteristics is specified as follows:

– If an alternative transfer characteristics SEI message is present for the CLVS, transferCharacteristics is set equal to preferred_transfer_characteristics;

– Otherwise, (an alternative transfer characteristics SEI message is not present for the CLVS), transferCharacteristics is set equal to vui_transfer_characteristics.

The content colour volume SEI message shall not be present, and decoders shall ignore it, when any of the following conditions is true:

– Any of the values of transferCharacteristics, vui_colour_primaries, and vui_matrix_coeffs has a value defined as unknown or unspecified.

– The value of vui_transfer_characteristics is equal to 2, 4, or 5.

– The value of vui_colour_primaries is equal to 2.

The following applies when converting the signal from a non-linear to a linear representation:

– If the value of transferCharacteristics is equal to 1, 6, 7, 14, or 15, the Rec. ITU-R BT.1886 reference electro-optical transfer function should be used to convert the signal to its linear representation, where the value of screen luminance for white is set equal to 100 candelas per square metre, the value of screen luminance for black is set equal to 0 candelas per square metre, and the value of the exponent of the power function is set equal to 2.4.

– Otherwise, if the value of transferCharacteristics is equal to 18, the hybrid log-gamma reference electro-optical transfer function specified in Rec. ITU-R BT.2100 should be used to convert the signal to its linear representation, where the value of nominal peak luminance of the display is set equal to 1000 candelas per square metre, the value of the display luminance for black is set equal to 0 candelas per square metre, and the value of system gamma is set equal to 1.2.

– Otherwise (the value of transferCharacteristics is not equal to 1, 6, 7, 14, 15, or 18) when the content colour volume SEI message is present, the exact inverse of the transfer function specified in specified in the VUI parameters should be used to convert the non-linear signal to a linear representation.

ccv_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous content colour volume SEI message in output order that applies to the current layer. ccv_cancel_flag equal to 0 indicates that content colour volume information follows.

ccv_persistence_flag specifies the persistence of the content colour volume SEI message for the current layer.

ccv_persistence_flag equal to 0 specifies that the content colour volume applies to the current decoded picture only.

ccv_persistence_flag equal to 1 specifies that the content colour volume SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a content colour volume SEI message is output that follows the current picture in output order.

ccv_primaries_present_flag equal to 1 specifies that the syntax elements ccv_primaries_x[c] and ccv_primaries_y[c] are present. ccv_primaries_present_flag equal to 0 specifies that the syntax elements ccv_primaries_x[c] and ccv_primaries_y[c] are not present.

ccv_min_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_min_luminance_value is present. ccv_min_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_min_luminance_value is not present.

ccv_max_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_max_luminance_value is present. ccv_max_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_max_luminance_value is not present.

ccv_avg_luminance_value_present_flag equal to 1 specifies that the syntax element ccv_avg_luminance_value is present. ccv_avg_luminance_value_present_flag equal to 0 specifies that the syntax element ccv_avg_luminance_value is not present.

It is a requirement of bitstream conformance that the values of ccv_primaries_present_flag, ccv_min_luminance_value_present_flag, ccv_max_luminance_value_present_flag, and ccv_avg_luminance_value_present_flag shall not all be equal to 0.

ccv_reserved_zero_2bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for reserved_zero_2bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of reserved_zero_2bits[i].

ccv_primaries_x[c] and **ccv_primaries_y**[c] specify the normalized x and y chromaticity coordinates, respectively, of the colour primary component c of the nominal content colour volume, according to the CIE 1931 definition of x and y as specified in ISO/CIE 11664-1 (see also ISO/CIE 11664-3 and CIE 15), in normalized increments of 0.00002. For describing colour volumes that use red, green, and blue colour primaries, it is suggested that index value c equal to 0 should correspond to the green primary, c equal to 1 should correspond to the blue primary, and c equal to 2 should correspond to the red colour primary specified in the VUI parameters.

The values of ccv_primaries_x[c] and ccv_primaries_y[c] shall be in the range of −5 000 000 to 5 000 000, inclusive.

When ccv_primaries_x[c] and ccv_primaries_y[c] are not present, they are inferred to be equal to the normalized x and y chromaticity coordinates, respectively, specified by vui_colour_primaries.

ccv_min_luminance_value specifies the normalized minimum luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in the VUI parameters according to the indicated transfer characteristics of the signal. The values of ccv_min_luminance_value are in normalized increments of 0.0000001.

ccv_max_luminance_value specifies the maximum luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in the VUI parameters according to the transfer characteristics of the signal. The values of ccv_max_luminance_value are in normalized increments of 0.0000001.

ccv_avg_luminance_value specifies the average luminance value, according to CIE 1931, that is expected to be present in the content, where values are normalized to L_o or L_c as specified in the VUI parameters according to the transfer characteristics of the signal. The values of ccv_avg_luminance_value are in normalized increments of 0.0000001.

NOTE – The resulting domain from this conversion process might or might not represent light in a source or display domain – it is merely a gamut representation domain rather than necessarily being a representation of actual light in either the scene or display domain. Therefore, the values corresponding to ccv_min_luminance_value, ccv_max_luminance_value, and ccv_avg_luminance_value might not necessarily correspond to a true luminance value.

The value of ccv_min_luminance_value, when present, shall be less than or equal to ccv_avg_luminance_value, when present. The value of ccv_avg_luminance_value, when present, shall be less than or equal to ccv_max_luminance_value, when present. The value of ccv_min_luminance_value, when present, shall be less than or equal to ccv_max_luminance_value, when present.

When the visually relevant region does not correspond to the entire cropped decoded picture, such as for "letterbox" encoding of video content with a wide picture aspect ratio within a taller cropped decoded picture, the indicated ccv_min_luminance_value, ccv_max_luminance_value, and ccv_avg_luminance_value should correspond only to values within the visually relevant region.

8.15 Omnidirectional video specific SEI messages

8.15.1 Sample location remapping process

8.15.1.1 General

Use of this process requires the definition of the following variable:

– A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.

To remap colour sample locations of a region-wise packed picture to a unit sphere, the following ordered steps are applied:

1. A region-wise packed picture is obtained as the cropped decoded picture by decoding a coded picture. For purposes of interpretation of chroma samples, the input to the indicated remapping process is the set of decoded sample values after applying an (unspecified) upsampling conversion process to the 4:4:4 colour sampling format as necessary when ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format). This (unspecified) upsampling process should account for the relative positioning relationship between the luma and chroma samples as indicated by vui_chroma_sample_loc_type_frame, vui_chroma_sample_loc_type_top_field, and vui_chroma_sample_loc_type_bottom_field syntax elements in the VUI parameters, when present.

2. If RWP is indicated, the sample locations of the region-wise packed picture are converted to sample locations of the respective projected picture as specified in clause 8.15.1.4. Otherwise, the projected picture is identical to the region-wise packed picture.

3. If frame packing is indicated, the sample locations of the projected picture are converted to sample locations of the respective constituent picture of the projected picture, as specified in clause 8.15.1.5. Otherwise, the constituent picture of the projected picture is identical to the projected picture.

4. The sample locations of a constituent picture of the projected picture are converted to sphere coordinates relative to the local coordinate axes, as specified in clause 8.15.1.2.

5. If rotation is indicated, the sphere coordinates relative to the local coordinate axes are converted to sphere coordinates relative to the global coordinate axes, as specified in clause 8.15.1.3. Otherwise, the global coordinate axes are identical to the local coordinate axes.

The overall process for mapping of luma sample locations within a region-wise packed picture to sphere coordinates relative to the global coordinate axes is normatively specified in clause 8.15.1.5.

For each region-wise packed picture corresponding to a decoded picture, the following applies:

– When an equirectangular projection SEI message with erp_cancel_flag equal to 0 that applies to the picture is present, ErpFlag is set equal to 1, and CmpFlag is set equal to 0.

– When a generalized cubemap projection SEI message with gcmp_cancel_flag equal to 0 that applies to the picture is present, CmpFlag is set equal to 1, and ErpFlag is set equal to 0.

– If a sphere rotation SEI message with sphere_rotation_cancel_flag equal to 0 that applies to the picture is present, RotationFlag is set equal to 1, and RotationYaw, RotationPitch, and RotationRoll are set equal to yaw_rotation $\div 2^{16}$, pitch_rotation $\div 2^{16}$, and roll_rotation $\div 2^{16}$, respectively.

– Otherwise, RotationFlag is set equal to 0.

– If a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0 that applies to the picture is not present, StereoFlag, TopBottomFlag, and SideBySideFlag are all set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– Otherwise, the following applies:

  – StereoFlag is set equal to 1.

  – If the value of fp_arrangement_type of the frame packing arrangement SEI message is equal to 3, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 1, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

  – Otherwise, if the value of fp_arrangement_type of the frame packing arrangement SEI message is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 2.

  – Otherwise, TopBottomFlag is set equal to 0, SideBySideFlag is set equal to 0, HorDiv1 is set equal to 1, and VerDiv1 is set equal to 1.

– If a RWP SEI message with rwp_cancel_flag equal to 0 that applies to the picture is not present, RegionWisePackingFlag is set equal to 0, and ConstituentPicWidth and ConstituentPicHeight are set to be equal to cropPicWidth / HorDiv1 and cropPicHeight / VerDiv1, respectively, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture.

– Otherwise, RegionWisePackingFlag is set equal to 1, and ConstituentPicWidth and ConstituentPicHeight are set equal to rwp_proj_picture_width / HorDiv1 and rwp_proj_picture_height / VerDiv1, respectively.

8.15.1.2 Projection for one sample location

Inputs to this process are:

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units (see clause 8.15.5.2), and

– the centre point of a sample location (hPos, vPos) along the horizontal and vertical axes, respectively, in relative projected picture sample units, where hPos and vPos could have non-integer real values.

Outputs of this process are:

– sphere coordinates (ϕ, θ) for the sample location in degrees relative to the local coordinate axes.

The projection for a sample location is derived as follows:

– If ErpFlag is equal to 1, the following applies:

  – If RegionWisePackingFlag is equal to 0 and erp_guard_band_flag is equal to 1, the following applies:

$$\begin{aligned}&\text{hPos}' = \text{hPos} - \text{erp\_left\_guard\_band\_width}\\&\text{pictureWidth} = \text{pictureWidth} - \text{erp\_left\_guard\_band\_width} - \text{erp\_right\_guard\_band\_width}\end{aligned} \tag{33}$$

  – Otherwise, the following applies:

$$\text{hPos}' = \text{hPos} \tag{34}$$

  – The following applies:

$$\begin{aligned}&\phi = 180 - \text{hPos}' * (360 \div \text{pictureWidth})\\&\theta = 90 - \text{vPos} * (180 \div \text{pictureHeight})\end{aligned} \tag{35}$$

– Otherwise (CmpFlag is equal to 1), the outputs are derived by the following ordered steps:

1. Clause 8.15.1.7 is invoked with pictureWidth and pictureHeight as inputs, and the output is assigned to faceWidth and faceHeight.
2. Clause 8.15.1.8 is invoked with hPos, vPos, faceWidth, and faceHeight, where hPos and vPos are within a projected picture, and the output is assigned to hPosFace and vPosFace within a projected face.
3. Clause 8.15.1.9 is invoked with hPosFace, vPosFace, faceWidth, and faceHeight, and the output is assigned to hPosRot and vPosRot.
4. If gcmp_packing_type is equal to 4 or 5, clause 8.15.1.1.10 is invoked with hPosRot, vPosRot, faceWidth, and faceHeight, and the output is assigned to hPosAdj and vPosAdj. Otherwise, hPosAdj and vPosAdj are identical to hPosRot and vPosRot, respectively.
5. The following applies:

$$\begin{aligned}&\text{hPos}' = -(\, 2 * \text{hPosAdj} \div \text{faceWidth}\,) + 1\\&\text{vPos}' = -(\, 2 * \text{vPosAdj} \div \text{faceHeight}\,) + 1\end{aligned} \quad (36)$$

– If gcmp_mapping_function_type is equal to 0, the following applies:

$$\begin{aligned}&\text{hPos}'' = \text{hPos}'\\&\text{vPos}'' = \text{vPos}'\end{aligned} \quad (37)$$

– Otherwise, if gcmp_mapping_function_type is equal to 1, the following applies:

$$\begin{aligned}&\text{hPos}'' = \text{Tan}(\, \text{hPos}' * \pi \div 4\,)\\&\text{vPos}'' = \text{Tan}(\, \text{vPos}' * \pi \div 4\,)\end{aligned} \quad (38)$$

– Otherwise (gcmp_mapping_function_type is equal to 2), the following applies:

$$\begin{aligned}&\text{coeffU[n]} = (\, \text{gcmp\_function\_coeff\_u[n]} + 1\,) \div 128\\&\text{coeffV[n]} = (\, \text{gcmp\_function\_coeff\_v[n]} + 1\,) \div 128\\&\text{hPos}'' = \text{hPos}' \div (\, 1 + \text{coeffU[n]} * (\, 1 - \text{gcmp\_function\_u\_affected\_by\_v\_flag[n]} * \text{vPos}'^2\,) *\\&\qquad (\, 1 - \text{hPos}'^2\,)\,)\\&\text{vPos}'' = \text{vPos}' \div (\, 1 + \text{coeffV[n]} * (\, 1 - \text{gcmp\_function\_v\_affected\_by\_u\_flag[n]} * \text{hPos}'^2\,) *\\&\qquad (\, 1 - \text{vPos}'^2\,)\,)\end{aligned} \quad (39)$$

– The following applies:

```
if( gcmp_face_index[ n ]  = =  0 ) { /* positive x front face */
  x = 1.0
  y = hPos″
  z = vPos″
} else if( gcmp_face_index[ n ]  = =  1 ) { /* negative x back face */
  x = −1.0
  y = −vPos″
  z = −hPos″
} else if( gcmp_face_index[ n ]  = =  2 ) { /* positive z top face */          (40)
  x = −hPos″
  y = −vPos″
  z = 1.0
} else if( gcmp_face_index[ n ]  = =  3 ) { /* negative z bottom face */
  x = hPos″
  y = −vPos″
  z = −1.0
} else if( gcmp_face_index[ n ]  = =  5 ) { /* positive y left face */
  x = −hPos″
  y = 1.0
  z = vPos″
} else { /* ( gcmp_face_index[ n ]  = =  4 ), negative y right face */
  x = hPos″
  y = −1.0
  z = vPos″
}
ϕ = Atan2( y, x ) * 180 ÷ π
θ =  Asin( z ÷ Sqrt( x² + y² + z² ) ) * 180 ÷ π
```

8.15.1.3 Conversion from the local coordinate axes to the global coordinate axes

Inputs to this process are:

– rotation_yaw (α_d), rotation_pitch (β_d), rotation_roll (γ_d), all in units of degrees, and

– sphere coordinates (ϕ_d, θ_d) relative to the local coordinate axes.

Outputs of this process are:

– sphere coordinates (ϕ', θ') relative to the global coordinate axes.

The outputs are derived as follows:

$$
\begin{array}{l}
\phi = \phi_d * \pi \div 180 \\
\theta = \theta_d * \pi \div 180 \\
\alpha = \alpha_d * \pi \div 180 \\
\beta = \beta_d * \pi \div 180 \\
\gamma = \gamma_d * \pi \div 180 \\
x_1 = \mathrm{Cos}(\ \phi\ ) * \mathrm{Cos}(\ \theta\ ) \\
y_1 = \mathrm{Sin}(\ \phi\ ) * \mathrm{Cos}(\ \theta\ ) \\
z_1 = \mathrm{Sin}(\ \theta\ ) \\
x_2 = \mathrm{Cos}(\ \beta\ ) * \mathrm{Cos}\ (\ \alpha\ ) * x_1 - \mathrm{Cos}(\ \beta\ ) * \mathrm{Sin}(\ \alpha\ ) * y_1 + \mathrm{Sin}(\ \beta\ ) * z_1 \\
y_2 = (\ \mathrm{Cos}(\ \gamma\ ) * \mathrm{Sin}(\ \alpha\ ) + \mathrm{Sin}(\ \gamma\ ) * \mathrm{Sin}(\ \beta\ ) * \mathrm{Cos}(\ \alpha\ )\ ) * x_1 + \\
\qquad (\ \mathrm{Cos}(\ \gamma\ ) * \mathrm{Cos}(\ \alpha\ ) - \mathrm{Sin}(\ \gamma\ ) * \mathrm{Sin}(\ \beta\ ) * \mathrm{Sin}(\ \alpha\ )\ ) * y_1 - \\
\qquad \mathrm{Sin}(\ \gamma\ ) * \mathrm{Cos}(\ \beta\ ) * z_1 \\
z_2 = (\ \mathrm{Sin}(\ \gamma\ ) * \mathrm{Sin}(\ \alpha\ ) - \mathrm{Cos}(\ \gamma\ ) * \mathrm{Sin}(\ \beta\ ) * \mathrm{Cos}(\ \alpha\ )\ ) * x_1 + \\
\qquad (\ \mathrm{Sin}(\ \gamma\ ) * \mathrm{Cos}(\ \alpha\ ) + \mathrm{Cos}(\ \gamma\ ) * \mathrm{Sin}(\ \beta\ ) * \mathrm{Sin}(\ \alpha\ )\ ) * y_1 + \\
\qquad \mathrm{Cos}(\ \gamma\ ) * \mathrm{Cos}(\ \beta\ ) * z_1 \\
\phi' = \mathrm{Atan2}(\ y_2, x_2\ ) * 180 \div \pi \\
\theta' = \mathrm{Asin}(\ z_2\ ) * 180 \div \pi
\end{array}
\tag{41}
$$

8.15.1.4 Conversion of sample locations for rectangular region-wise packing

Inputs to this process are:

– sample location (x, y) within the packed region, where x and y are in relative region-wise packed picture sample units, while the sample location is at an integer sample location within the packed picture,

– the width and the height (projRegWidth, projRegHeight) of the projected region, in relative projected picture sample units,

– the width and the height (packedRegWidth, packedRegHeight) of the packed region, in relative region-wise packed picture sample units,

– transform type (transformType), and

– offset values for the sampling position (offsetX, offsetY) in the range of 0, inclusive, to 1, exclusive, in horizontal and vertical relative region-wise packed picture sample units, respectively.

NOTE – offsetX and offsetY both being equal to 0.5 indicates a sampling position that is at the centre point of a sample in packed picture sample units.

Outputs of this process are:

– the centre point of the sample location (hPos, vPos) within the projected region in relative projected picture sample units, where hPos and vPos could have non-integer real values.

The outputs are derived as follows:

```
if( transformType = = 0 || transformType = = 1 || transformType = = 2 || transformType = = 3 ) {
      horRatio = projRegWidth ÷ packedRegWidth
      verRatio = projRegHeight ÷ packedRegHeight
} else if ( transformType = = 4 || transformType = = 5 || transformType = = 6 ||
            transformType = = 7 ) {
      horRatio = projRegWidth ÷ packedRegHeight
      verRatio = projRegHeight ÷ packedRegWidth
}
if( transformType = = 0 ) {
      hPos = horRatio * ( x + offsetX )
```

```
      vPos = verRatio * ( y + offsetY )
} else if ( transformType  = =  1 ) {
      hPos = horRatio * ( packedRegWidth − x − offsetX )
      vPos = verRatio * ( y + offsetY )
} else if ( transformType  = =  2 ) {
      hPos = horRatio * ( packedRegWidth − x − offsetX )
      vPos = verRatio * ( packedRegHeight − y − offsetY )                    (42)
} else if ( transformType  = =  3 ) {
      hPos = horRatio * ( x + offsetX )
      vPos = verRatio * ( packedRegHeight − y − offsetY )
} else if ( transformType  = =  4 ) {
      hPos = horRatio * ( y + offsetY )
      vPos = verRatio * ( x + offsetX )
} else if ( transformType  = =  5 ) {
      hPos = horRatio * ( y + offsetY )
      vPos = verRatio * ( packedRegWidth − x − offsetX )
} else if ( transformType  = = 6 ) {
      hPos = horRatio * ( packedRegHeight − y − offsetY )
      vPos = verRatio * ( packedRegWidth − x − offsetX )
} else if ( transformType  = =  7 ) {
      hPos = horRatio * ( packedRegHeight − y − offsetY )
      vPos = verRatio * ( x + offsetX )
}
```

8.15.1.5 Mapping of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes

This clause specifies the semantics of luma sample locations within a cropped decoded picture to sphere coordinates relative to the global coordinate axes.

offsetX is set equal to 0.5 and offsetY is set equal to 0.5.

If RegionWisePackingFlag is equal to 1, the following applies for each packed region n in the range of 0 to NumPackedRegions − 1, inclusive:

– For each sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region, the following applies:
  – The corresponding sample location (xProjPicture, yProjPicture) of the projected picture is derived as follows:
    – x is set equal to xPackedPicture − PackedRegionLeft[n].
    – y is set equal to yPackedPicture − PackedRegionTop[n].
    – Clause 8.15.1.4 is invoked with x, y, PackedRegionWidth[n], PackedRegionHeight[n], ProjRegionWidth[n], ProjRegionHeight[n], TransformType[n], offsetX and offsetY as inputs, and the output is assigned to sample location (hPos, vPos).
    – xProjPicture is set equal to ProjRegionLeft[n] + hPos.
    – When StereoFlag is equal to 0 or TopBottomFlag is equal to 1, and when xProjPicture is greater than or equal to rwp_proj_picture_width, xProjPicture is set equal to xProjPicture − rwp_proj_picture_width.
    – When SideBySideFlag is equal to 1, the following applies:
      – When ProjRegionLeft[n] is less than rwp_proj_picture_width / 2 and xProjPicture is greater than or equal to rwp_proj_picture_width / 2, xProjPicture is set equal to xProjPicture − rwp_proj_picture_width / 2.
      – When ProjRegionLeft[n] is greater than or equal to rwp_proj_picture_width / 2 and xProjPicture is greater than or equal to rwp_proj_picture_width, xProjPicture is set equal to xProjPicture − rwp_proj_picture_width / 2.
    – yProjPicture is set equal to ProjRegionTop[n] + vPos.
  – Clause 8.15.1.6 is invoked with xProjPicture, yProjPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the luma sample location (xPackedPicture, yPackedPicture) belonging to the n-th packed region in the decoded picture.

Otherwise if RegionWisePackingFlag is equal 0 and CmpFlag is equal to 1, the following applies for each sample location (x, y) that is not a cubemap projection guard band sample within the cropped decoded picture:

– xProjPicture is set equal to x + offsetX.

– yProjPicture is set equal to y + offsetY.

– Clause 8.15.1.6 is invoked with xProjPicture, yProjPicture, ConstituentPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the sample location (x, y) within the cropped decoded picture.

Otherwise (RegionWisePackingFlag is equal to 0, and CmpFlag is equal to 0), the following applies for each sample location (x, y) that is not an equirectangular projection guard band sample within the cropped decoded picture, where a sample location (x, y) is an equirectangular projection guard band sample when and only when ErpFlag is equal to 1, x is in the range of 0 to erp_left_guard_band_width − 1, inclusive, or ConstituentPicWidth − erp_right_guard_band_width to ConstituentPicWidth − 1, inclusive, and y is in the range of 0 to ConstituentPicHeight − 1, inclusive:

– xProjPicture is set equal to x + offsetX.

– yProjPicture is set equal to y + offsetY.

– If ErpFlag is equal to 0, projPicWidth is set equal to ConstituentPicWidth. Otherwise (ErpFlag is equal to 1), projPicWidth is set equal to ConstituentPicWidth − (erp_left_guard_band_width + erp_right_guard_band_width).

– Clause 8.15.1.6 is invoked with xProjPicture, yProjPicture, projPicWidth, and ConstituentPicHeight as inputs, and the outputs indicating the sphere coordinates and the constituent picture index (for frame-packed stereoscopic video) for the sample location (x, y) within the region-wise packed picture.

8.15.1.6 Conversion from a sample location in a projected picture to sphere coordinates relative to the global coordinate axes

Inputs to this process are:

– the centre point of a sample location (xProjPicture, yProjPicture) within a projected picture, where xProjPicture and yProjPicture are in relative projected picture sample units and could have non-integer real values, and

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units.

Outputs of this process are:

– sphere coordinates (azimuthGlobal, elevationGlobal), in units of degrees relative to the global coordinate axes, and

– when StereoFlag is equal to 1, the index of the constituent picture (constituentPicture) equal to 0 or 1.

The outputs are derived with the following ordered steps:

1. constituentPicture, xProjPicture, and yProjPicture are conditionally set as follows:
   – If xProjPicture is greater than or equal to pictureWidth or yProjPicture is greater than or equal to pictureHeight, the following applies:
     – constituentPicture is set equal to 1.
     – When xProjPicture is greater than or equal to pictureWidth, xProjPicture is set to xProjPicture − pictureWidth.
     – When yProjPicture is greater than or equal to pictureHeight, yProjPicture is set to yProjPicture − pictureHeight.
   – Otherwise, constituentPicture is set equal to 0.
2. Clause 8.15.1.2 is invoked with pictureWidth, pictureHeight, xProjPicture, and yProjPicture as inputs, and the output is assigned to azimuthLocal, elevationLocal.
3. azimuthGlobal and elevationGlobal are set as follows:
   – If RotationFlag is equal to 1, clause 8.15.1.3 is invoked with azimuthLocal, elevationLocal, RotationYaw, RotationPitch, and RotationRoll as inputs, and the output is assigned to azimuthGlobal and elevationGlobal.
   – Otherwise, azimuthGlobal is set equal to azimuthLocal and elevationGlobal is set equal to elevationLocal.

8.15.1.7 Calculation of the cubemap face size for a projected picture

Inputs to this process are:

– pictureWidth and pictureHeight, which are the width and height, respectively, of a monoscopic projected luma picture, in relative projected picture sample units.

Outputs of this process are:

– faceWidth and faceHeight, which are the width and height, respectively, of a projected face, in relative projected picture sample units.

The outputs are derived as follows:

```
gcmpPicWidth = pictureWidth
gcmpPicHeight = pictureHeight
gcmpGuardBandSamples = gcmp_guard_band_flag ? gcmp_guard_band_samples_minus1 + 1 : 0
if( gcmp_guard_band_flag  &&  gcmp_guard_band_boundary_exterior_flag ) {
    gcmpPicWidth = pictureWidth − 2 * gcmpGuardBandSamples
    gcmpPicHeight = pictureHeight − 2 * gcmpGuardBandSamples
}
if( gcmp_packing_type  = =  0 ) {
    if( gcmp_guard_band_flag )
        gcmpPicHeight  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth
    faceHeight = gcmpPicHeight / 6
} else if( gcmp_packing_type  = =  1 ) {
    if( gcmp_guard_band_flag )
        gcmpPicWidth  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth / 2
    faceHeight = gcmpPicHeight / 3
} else if( gcmp_packing_type  = =  2 ) {
    if( gcmp_guard_band_flag )
        gcmpPicHeight  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth / 3
    faceHeight = gcmpPicHeight / 2                                        (43)
} else if( gcmp_packing_type  = =  3 ) {
    if( gcmp_guard_band_flag )
        gcmpPicWidth  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth / 6
    faceHeight = gcmpPicHeight
} else if( gcmp_packing_type  = =  4 ) {
    if( gcmp_guard_band_flag )
        gcmpPicWidth  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth / 3
    faceHeight = gcmpPicHeight
} else if( gcmp_packing_type  = =  5 ) {
    if( gcmp_guard_band_flag )
        gcmpPicHeight  −=  2 * gcmpGuardBandSamples
    faceWidth = gcmpPicWidth
    faceHeight = gcmpPicHeight / 3
}
```

The values of faceWidth and faceHeight are constrained as follows:

– If gcmp_packing_type is equal to 4, the following constraints apply:

  – When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), faceWidth shall be a multiple of 4 in units of luma samples.

  – When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), faceHeight shall be a multiple of 2 in units of luma samples.

– Otherwise, if gcmp_packing_type is equal to 5, the following constraints apply:

  – When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), faceWidth shall be a multiple of 2 in units of luma samples.

– When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), faceHeight shall be a multiple of 4 in units of luma samples.

– Otherwise, the following constraints apply:

  – When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), faceWidth shall be a multiple of 2 in units of luma samples.

  – When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), faceHeight shall be a multiple of 2 in units of luma samples.

It is a requirement of bitstream conformance that the following constraints apply:

– If gcmp_packing_type is equal to 0, gcmpPicHeight shall be a multiple of 6, and gcmpPicWidth shall be equal to gcmpPicHeight / 6.

– Otherwise, if gcmp_packing_type is equal to 1, gcmpPicWidth shall be a multiple of 2 and gcmpPicHeight shall be a multiple of 3, and gcmpPicWidth / 2 shall be equal to gcmpPicHeight / 3.

– Otherwise, if gcmp_packing_type is equal to 2, gcmpPicWidth shall be a multiple of 3 and gcmpPicHeight shall be a multiple of 2, and gcmpPicWidth / 3 shall be equal to gcmpPicHeight / 2.

– Otherwise, if gcmp_packing_type is equal to 3, gcmpPicWidth shall be a multiple of 6, and gcmpPicWidth / 6 shall be equal to gcmpPicHeight.

– Otherwise, if gcmp_packing_type is equal to 4, gcmpPicWidth shall be a multiple of 6, and gcmpPicWidth / 3 shall be equal to gcmpPicHeight.

– Otherwise, if gcmp_packing_type is equal to 5, gcmpPicHeight shall be a multiple of 6, and gcmpPicWidth shall be equal to gcmpPicHeight / 3.

8.15.1.8 Conversion from a sample location in a projected picture to a sample location in a projected cubemap face

Inputs to this process are:

– sample location (hPos, vPos) within the projected picture in relative projected picture sample units, where hPos and vPos could have non-integer real values, and

– faceWidth and faceHeight, which are the width and height, respectively, of the projected face, in relative projected picture sample units.

Outputs of this process are:

– the sample location (hPosFace, vPosFace) within the projected face in relative projected picture sample units, where hPosFace and vPosFace could have non-integer real values.

The outputs are derived as follows:

```
gbSize = gcmpGuardBandSamples
tmpHorPos = hPos
tmpVerPos = vPos
if( gcmp_guard_band_flag ) {
    if( gcmp_guard_band_boundary_exterior_flag ) {
        tmpHorPos = hPos − gbSize
        tmpVerPos = vPos − gbSize
    }
    if( gcmp_packing_type  = =  0 )
        tmpVerPos = tmpVerPos < 3 * faceHeight ? tmpVerPos : tmpVerPos − 2 * gbSize
    else if( gcmp_packing_type  = =  1 )
        tmpHorPos = tmpHorPos < faceWidth ? tmpHorPos : tmpHorPos − 2 * gbSize
    else if( gcmp_packing_type  = =  2 )
        tmpVerPos = tmpVerPos < faceHeight ? tmpVerPos : tmpVerPos − 2 * gbSize          (44)
    else if( gcmp_packing_type  = =  3 )
        tmpHorPos = tmpHorPos < 3 * faceWidth ? tmpHorPos : tmpHorPos − 2 * gbSize
    else if( gcmp_packing_type  = =  4 )
        tmpHorPos = tmpHorPos < faceWidth / 2 ? tmpHorPos : tmpHorPos < 2.5 * faceWidth + gbSize ?
                tmpHorPos − gbSize : tmpHorPos − 2 * gbSize
    else if( gcmp_packing_type  = =  5 )
        tmpVerPos = tmpVerPos < faceHeight / 2 ? tmpVerPos : tmpVerPos < 2.5 * faceHeight + gbSize ?
```

```
                    tmpVerPos − gbSize : tmpVerPos − 2 * gbSize
}
w = Floor( tmpHorPos ÷ faceWidth )
h = Floor( tmpVerPos ÷ faceHeight )
hPosFace = tmpHorPos − w * faceWidth
vPosFace = tmpVerPos − h * faceHeight
```

8.15.1.9 Rotation of sample locations for a projected cubemap face

Inputs to this process are:

– sample location (hPosFace, vPosFace) within the n-th projected face in relative projected picture sample units, where hPosFace and vPosFace could have non-integer real values, and

– faceWidth and faceHeight, which are the width and height, respectively, of the projected face, in relative projected picture sample units.

Outputs of this process are:

– the rotated sample location (hPosRot, vPosRot) within the projected face in relative projected picture sample units, where hPosRot and vPosRot could have non-integer real values.

The outputs are derived as follows:

```
if( gcmp_face_rotation[ n ]  = =  0 ) {
    hPosRot = hPosFace
    vPosRot = vPosFace
} else if( gcmp_face_rotation[ n ]  = =  1 ) {
    hPosRot = vPosFace
    vPosRot = faceWidth − hPosFace                                        (45)
} else if( gcmp_face_rotation[ n ]  = =  2 ) {
    hPosRot = faceWidth − hPosFace
    vPosRot = faceHeight − vPosFace
} else if( gcmp_face_rotation[ n ]  = =  3 ) {
    hPosRot = faceHeight − vPosFace
    vPosRot = hPosFace
}
```

8.15.1.10 Adjustment of a sample location for hemisphere cubemap projection

Inputs to this process are:

– sample location (hPosRot, vPosRot) within the n-th projected face in relative projected picture sample units, where hPosRot and vPosRot could have non-integer real values, and

– faceWidth and faceHeight, which are the width and height, respectively, of the projected face, in relative projected picture sample units.

Outputs of this process are:

– the adjusted sample location (hPosAdj, vPosAdj) within the n-th projected face in relative projected picture sample units, where hPosAdj and vPosAdj could have non-integer real values.

The outputs are derived as follows:

```
leftFaceIdx = {5, 3, 1, 0, 0, 1}
rightFaceIdx = {4, 2, 0, 1, 1, 0}
topFaceIdx = {2, 4, 4, 4, 2, 2}
bottomFaceIdx = {3, 5, 5, 5, 3, 3}
hPosAdj = hPosRot
vPosAdj = vPosRot                                                         (46)
if( n  !=  2 )
    if( face_index[ 2 ]  = =  leftFaceIdx[ face_index[ n ] ]  &&  hPosAdj  >=  faceWidth / 2 )
        hPosAdj  −=  faceWidth / 2
    else if( face_index[ 2 ]  = =  rightFaceIdx[ face_index[ n ] ]  &&  hPosAdj < faceWidth / 2 )
        hPosAdj  +=  faceWidth / 2
    else if( face_index[ 2 ]  = =  topFaceIdx[ face_index[ n ] ]  &&  vPosAdj  >=  faceHeight / 2 )
        vPosAdj  −=  faceHeight / 2
```

```
else if( face_index[ 2 ] = = bottomFaceIdx[ face_index[ n ] ] && vPosAdj < faceHeight / 2 )
    vPosAdj += faceHeight / 2
```

8.15.2 Equirectangular projection SEI message

8.15.2.1 Equirectangular projection SEI message syntax

equirectangular_projection(payloadSize) {	**Descriptor**
erp_cancel_flag	u(1)
if(!erp_cancel_flag) {	
erp_persistence_flag	u(1)
erp_guard_band_flag	u(1)
erp_reserved_zero_2bits	u(2)
if(erp_guard_band_flag = = 1) {	
erp_guard_band_type	u(3)
erp_left_guard_band_width	u(8)
erp_right_guard_band_width	u(8)
}	
}	
}	

8.15.2.2 Equirectangular projection SEI message semantics

The equirectangular projection SEI message provides information to enable remapping (through an equirectangular projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

Use of this SEI message requires the definition of the following variable:

– A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.

When an equirectangular projection SEI message is present for any picture of a CLVS, an equirectangular projection SEI message shall be present for the first picture of the CLVS and no SEI message indicating a different type of projection shall be present for any picture of the CLVS.

When the SAR for a picture is indicated by vui_aspect_ratio_idc or sari_aspect_ratio_idc greater than 1, there should be no equirectangular projection SEI messages applicable for the picture.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

– The value of fp_arrangement_cancel_flag is equal to 0.
– The value of fp_arrangement_type is equal to 3, 4, or 5.
– The value of fp_quincunx_sampling_flag is equal to 0.
– The value of fp_spatial_flipping_flag is equal to 0.
– The value of fp_field_views_flag is equal to 0.
– The value of fp_frame0_grid_position_x is equal to 0.
– The value of fp_frame0_grid_position_y is equal to 0.
– The value of fp_frame1_grid_position_x is equal to 0.
– The value of fp_frame1_grid_position_y is equal to 0.

When a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message, an equirectangular projection SEI message with erp_cancel_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore equirectangular projection SEI messages when a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message.

erp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous equirectangular projection SEI message in output order. erp_cancel_flag equal to 0 indicates that equirectangular projection information follows.

erp_persistence_flag specifies the persistence of the equirectangular projection SEI message for the current layer.

erp_persistence_flag equal to 0 specifies that the equirectangular projection SEI message applies to the current decoded picture only.

erp_persistence_flag equal to 1 specifies that the equirectangular projection SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with an equirectangular projection SEI message is output that follows the current picture in output order.

erp_guard_band_flag equal to 1 indicates that the constituent picture contains guard band areas for which the sizes are specified by the syntax elements erp_left_guard_band_width and erp_right_guard_band_width. erp_guard_band_flag equal to 0 indicates that the constituent picture does not contains guard band areas for which the sizes are specified by the syntax elements erp_left_guard_band_width and erp_right_guard_band_width.

erp_reserved_zero_2bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for erp_reserved_zero_2bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of erp_reserved_zero_2bits.

erp_guard_band_type indicates the type of the guard bands as follows:

– erp_guard_band_type equal to 0 indicates that the content of the guard band in relation to the content of the constituent picture is unknown or unspecified or specified by other means not specified in this Specification.

– erp_guard_band_type equal to 1 indicates that the content of the guard band suffices for interpolation of sample values at sub-pel sample fractional locations within the constituent picture.

NOTE – erp_guard_band_type equal to 1 could be used when the source boundary samples of a constituent picture have been copied horizontally to the guard band.

– erp_guard_band_type equal to 2 indicates that the content of the guard band represents actual picture content at a quality that gradually changes from the picture quality of the constituent picture to that of the spherically adjacent region.

– erp_guard_band_type equal to 3 indicates that the content of the guard bands represents actual picture content at a similar level of quality as the constituent picture.

– erp_guard_band_type values greater than 3 are reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value of erp_guard_band_type when the value is greater than 3 as equivalent to the value 0.

erp_left_guard_band_width specifies the width of the guard band on the left side of the constituent picture in units of luma samples. When erp_guard_band_flag is equal to 0, the value of erp_left_guard_band_width is inferred to be equal to 0. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), erp_left_guard_band_width shall be an even number.

erp_right_guard_band_width specifies the width of the guard band on the right side of the constituent picture in units of luma samples. When erp_guard_band_flag is equal to 0, the value of erp_right_guard_band_width is inferred to be equal to 0. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), erp_right_guard_band_width shall be an even number.

8.15.3 Generalized cubemap projection SEI message

8.15.3.1 Generalized cubemap projection SEI message syntax

generalized_cubemap_projection(payloadSize) {	**Descriptor**
gcmp_cancel_flag	u(1)
if(!gcmp_cancel_flag) {	
gcmp_persistence_flag	u(1)
gcmp_packing_type	u(3)
gcmp_mapping_function_type	u(2)
for(i = 0; i < (gcmp_packing_type = = 4 || gcmp_packing_type = = 5) ? 5 : 6; i++) {	
gcmp_face_index[i]	u(3)
gcmp_face_rotation[i]	u(2)
if(gcmp_mapping_function_type = = 2) {	
gcmp_function_coeff_u[i]	u(7)
gcmp_function_u_affected_by_v_flag[i]	u(1)
gcmp_function_coeff_v[i]	u(7)
gcmp_function_v_affected_by_u_flag[i]	u(1)
}	
}	
gcmp_guard_band_flag	u(1)
if(gcmp_guard_band_flag) {	
gcmp_guard_band_type	u(3)
gcmp_guard_band_boundary_exterior_flag	u(1)
gcmp_guard_band_samples_minus1	u(4)
}	
}	
}	

8.15.3.2 Generalized cubemap projection SEI message semantics

The generalized cubemap projection SEI message provides information to enable remapping (through a generalized cubemap projection) of the colour samples of the projected pictures onto a sphere coordinate space in sphere coordinates (ϕ, θ) for use in omnidirectional video applications for which the viewing perspective is from the origin looking outward toward the inside of the sphere. The sphere coordinates are defined so that ϕ is the azimuth (longitude, increasing eastward) and θ is the elevation (latitude, increasing northward).

Use of this SEI message requires the definition of the following variable:

– A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.

When a generalized cubemap projection SEI message is present for any picture of a CLVS, a generalized cubemap projection SEI message shall be present for the first picture of the CLVS and no SEI message indicating a different type of projection shall be present for any picture of the CLVS.

When the SAR for a picture is indicated by vui_aspect_ratio_idc or sari_aspect_ratio_idc greater than 1, there should be no generalized cubemap projection SEI messages applicable for the picture.

A frame packing arrangement SEI message for which all the following conditions are true is referred to as an effectively applicable frame packing arrangement SEI message:

– The value of fp_arrangement_cancel_flag is equal to 0.

– The value of fp_arrangement_type is equal to 3, 4, or 5.

– The value of fp_quincunx_sampling_flag is equal to 0.

– The value of fp_spatial_flipping_flag is equal to 0.
– The value of fp_field_views_flag is equal to 0.
– The value of fp_frame0_grid_position_x is equal to 0.
– The value of fp_frame0_grid_position_y is equal to 0.
– The value of fp_frame1_grid_position_x is equal to 0.
– The value of fp_frame1_grid_position_y is equal to 0.

When a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message, a generalized cubemap projection SEI message with gcmp_cancel_flag equal to 0 that applies to the picture shall not be present. Decoders shall ignore generalized cubemap projection SEI messages when a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0 that applies to the picture is present that is not an effectively applicable frame packing arrangement SEI message.

When all of the following conditions are true, the functionality of the generalized cubemap projection SEI message is exactly the same as the cubemap projection SEI message specified in in Rec. ITU-T H.265 | ISO/IEC 23008-2 and Rec. ITU-T H.264 | ISO/IEC 14496-10:

– The value of gcmp_packing_type is equal to 2;
– The value of gcmp_mapping_function_type is equal to 0;
– The values of gcmp_face_index[i] for i from 0 to 5, inclusive, are equal to 5, 0, 4, 3, 1 and 2, respectively;
– The value of gcmp_face_rotation[i] is equal to 0 for each value of i in the range of 0 to 5, inclusive;
– The value of gcmp_guard_band_flag is equal to 0.

gcmp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous generalized cubemap projection SEI message in output order. gcmp_cancel_flag equal to 0 indicates that cubemap projection information follows.

gcmp_persistence_flag specifies the persistence of the generalized cubemap projection SEI message for the current layer.

gcmp_persistence_flag equal to 0 specifies that the generalized cubemap projection SEI message applies to the current decoded picture only.

gcmp_persistence_flag equal to 1 specifies that the generalized cubemap projection SEI message applies to the current decoded picture and persists all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.
– The bitstream ends.
– A picture in the current layer in an AU associated with a cubemap projection SEI message is output that follows the current picture in output order.

gcmp_packing_type specifies the packing type and the position index of the cubemap packing as specified in Table 10. When the value of gcmp_packing_type is in the range of 0 to 3, inclusive, cubemap packing with six faces is used. When gcmp_packing_type is 4 or 5, hemisphere cubemap packing with one full face and four half faces is used. The value of gcmp_packing_type shall be in the range of 0 to 5, inclusive. Other values for gcmp_packing_type are reserved for future use by ITU-T | ISO/IEC.

Table 10 – Specification of packing type and position index based on gcmp_packing_type

gcmp_packing_type	Packing type and position index
0	0 1 2 3 4 5
1	0 1 2 3 4 5
2	0 1 2 3 4 5
3	0 1 2 3 4 5
4	0 1 2 3 4
5	0 1 2 3 4

gcmp_mapping_function_type specifies the mapping function used to adjust the sample locations of the cubemap projection. gcmp_mapping_function_type equal to 0 specifies that the same mapping function as specified for the cubemap projection SEI message in Rec. ITU-T H.265 | ISO/IEC 23008-2 and Rec. ITU-T H.264 | ISO/IEC 14496-10 is used. gcmp_mapping_function_type equal to 1 specifies that the equi-angular mapping function is applied to adjust the sample locations of the projected face, as defined in clause 8.15.1.2. gcmp_mapping_function_type equal to 2 specifies that the coefficients of the mapping function applied to adjust the sample locations of the i-th projected face are specified by the syntax elements gcmp_function_coeff_u[i], gcmp_function_u_affected_by_v_flag[i], gcmp_function_coeff_v[i], and gcmp_function_v_affected_by_u_flag[i]. The value of gcmp_mapping_function_type shall be in the range of 0 to 2, inclusive.

gcmp_face_index[i] specifies the face index for position index i in gcmp_packing_type and the relationship between the global coordinates 3D (X, Y, Z) and the local coordinate 2D (u, v) as specified in clause 8.15.1.2.

When gcmp_packing_type is equal to 4 or 5, it is a requirement of bitstream conformance that the following constraints apply:

– If gcmp_face_index[2] is equal to 0 or 1, the value of gcmp_face_index[i] for i equal to 0, 1, 3 or 4 shall be in the range of 2 to 5, inclusive.

– Otherwise, if gcmp_face_index[2] is equal to 2 or 3, the value of gcmp_face_index[i] for i equal to 0, 1, 3 or 4 shall be 0, 1, 4, or 5.

– Otherwise, the value of gcmp_face_index[i] for i equal to 0, 1, 3 or 4 shall be in the range of 0 to 3, inclusive.

gcmp_face_rotation[i] specifies the rotation to be applied to the face on position index i as specified in Table 11.

Table 11 – Specification of counterclockwise rotation angle based on gcmp_face_rotation[i]

gcmp_face_rotation[i]	Rotation angle in degree (anticlockwise)
0	0
1	90
2	180
3	270

When gcmp_packing_type is equal to 4, it is a requirement of bitstream conformance that the following constraints apply:

– If gcmp_face_index[2] is equal to 0 or 1, the value of gcmp_face_rotation[i] for i equal to 0, 1, 3 or 4 shall be 0 or 2.

– Otherwise, if gcmp_face_index[2] is equal to 2 or 3, when gcmp_face_index[i] is equal to 1, the value of gcmp_face_rotation[i] shall be 0 or 2, and when gcmp_face_index[i] is equal to 0, 4 or 5, the value of gcmp_face_rotation[i] shall be 1 or 3.

– Otherwise, when gcmp_face_index[i] is equal to 0, the value of gcmp_face_rotation[i] shall be 0 or 2, and when gcmp_face_index[i] is equal to 1, 2 or 3, the value of gcmp_face_rotation[i] shall be 1 or 3.

When gcmp_packing_type is equal to 5, it is a requirement of bitstream conformance that the following constraints apply:

– If gcmp_face_index[2] is equal to 0 or 1, the value of gcmp_face_rotation[i] for i equal to 0, 1, 3 or 4 shall be 1 or 3.

– Otherwise, if gcmp_face_index[2] is equal to 2 or 3, when gcmp_face_index[i] is equal to 1, the value of gcmp_face_rotation[i] shall be 1 or 3, and when gcmp_face_index[i] is equal to 0, 4 or 5, the value of gcmp_face_rotation[i] shall be 0 or 2.

– Otherwise, when gcmp_face_index[i] is equal to 0, the value of gcmp_face_rotation[i] shall be 1 or 3, and when gcmp_face_index[i] is equal to 1, 2 or 3, the value of gcmp_face_rotation[i] shall be 0 or 2.

gcmp_function_coeff_u[i] specifies the coefficient used in the cubemap mapping function of the u-axis of the i-th face. When gcmp_function_coeff_u[i] is not present, it is inferred to be equal to 0.

gcmp_function_u_affected_by_v_flag[i] equal to 1 indicates that the cubemap mapping function of the u-axis refers to the v position of the sample location. gcmp_function_u_affected_by_v_flag[i] equal to 0 indicates that the cubemap mapping function in u-axis does not refer to the v position of the sample location.

gcmp_function_coeff_v[i] specifies the coefficient used in the cubemap mapping function of the v-axis of the i-th face. When gcmp_function_coeff_v[i] is not present, it is inferred to be equal to 0.

gcmp_function_v_affected_by_u_flag[i] equal to 1 indicates that the cubemap mapping function of the v-axis refers to the u position of the sample location. gcmp_function_v_affected_by_u_flag[i] equal to 0 indicates that the cubemap mapping function in v-axis does not refer to the u position of the sample location.

gcmp_guard_band_flag equal to 0 indicates that the coded picture does not contain guard band areas. cmp_guard_band_flag equal to 1 indicates that the coded picture contains guard band areas for which the sizes are specified by the syntax element gcmp_guard_band_samples_minus1.

gcmp_guard_band_type indicates the type of the guard bands as follows:

– gcmp_guard_band_type equal to 0 indicates that the content of the guard bands in relation to the content of the coded face is unknown or unspecified or specified by other means not specified in this Specification.

– gcmp_guard_band_type equal to 1 indicates that the content of the guard bands suffices for interpolation of sample values at sub-pel sample fractional locations within the coded face.

NOTE – gcmp_guard_band_type equal to 1 could be used when the source boundary samples of a coded face have been copied horizontally or vertically to the guard band.

– gcmp_guard_band_type equal to 2 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the coded face at quality that gradually changes from the picture quality of the coded face to that of the spherically adjacent region.

– gcmp_guard_band_type equal to 3 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the coded face at a similar picture quality as within the coded face.

– gcmp_guard_band_type values greater than 3 are reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value of gcmp_guard_band_type when the value is greater than 3 as equivalent to the value 0.

gcmp_guard_band_boundary_exterior_flag indicates which face boundaries contain guard bands, as specified in Table 12.

Table 12 – Specification of guard band boundary location based on gcmp_packing_type and gcmp_guard_band_boundary_exterior_flag

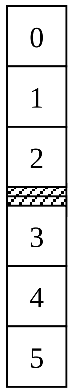
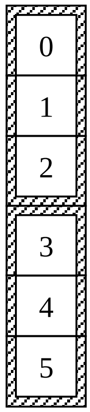
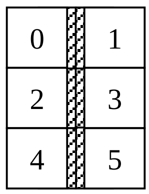
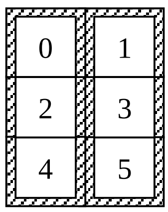
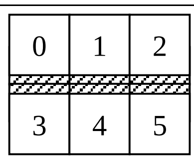
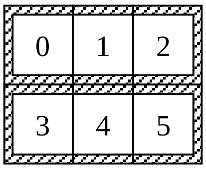
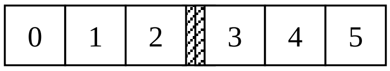
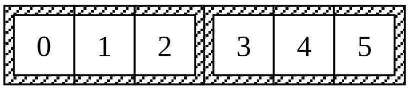
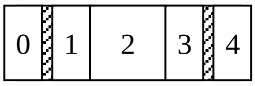
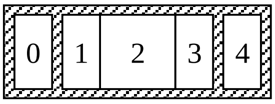
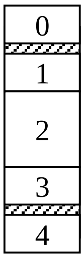
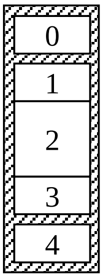
gcmp_packing_type	**gcmp_guard_band_boundary_exterior_flag**	**Location of guard band**
0	0	
0	1	
1	0	
1	1	
2	0	

Table 12 – Specification of guard band boundary location based on gcmp_packing_type and gcmp_guard_band_boundary_exterior_flag

gcmp_packing_type	gcmp_guard_band_boundary_exterior_flag	Location of guard band
2	1	
3	0	
3	1	
4	0	
4	1	
5	0	
5	1	

gcmp_guard_band_samples_minus1 plus 1 specifies the number of guard band samples, in units of luma samples, used in the cubemap projected picture. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), gcmp_guard_band_samples_minus1 plus 1 shall correspond to an even number of luma samples within the cropped decoded picture.

8.15.4 Sphere rotation SEI message

8.15.4.1 Sphere rotation SEI message syntax

sphere_rotation(payloadSize) {	**Descriptor**
sphere_rotation_cancel_flag	u(1)
if(!sphere_rotation_cancel_flag) {	
sphere_rotation_persistence_flag	u(1)
sphere_rotation_reserved_zero_6bits	u(6)
yaw_rotation	i(32)
pitch_rotation	i(32)

roll_rotation	i(32)
}	
}	

8.15.4.2 Sphere rotation SEI message semantics

The sphere rotation SEI message provides information on rotation angles yaw (α), pitch (β), and roll (γ) that are used for conversion between the global coordinate axes and the local coordinate axes.

Relative to an (x, y, z) Cartesian coordinate system, yaw expresses a rotation around the z (vertical, up) axis, pitch rotates around the y (lateral, side-to-side) axis, and roll rotates around the x (back-to-front) axis. Rotations are extrinsic, i.e., around x, y, and z fixed reference axes. The angles increase clockwise when looking from the origin towards the positive end of an axis.

sphere_rotation_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous sphere rotation SEI message in output order. sphere_rotation_cancel_flag equal to 0 indicates that sphere rotation information follows.

sphere_rotation_persistence_flag specifies the persistence of the sphere rotation SEI message for the current layer.

sphere_rotation_persistence_flag equal to 0 specifies that the sphere rotation SEI message applies to the current decoded picture only.

sphere_rotation_persistence_flag equal to 1 specifies that the sphere rotation SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a sphere rotation SEI message is output that follows the current picture in output order.

When no omnidirectional video projection is indicated to apply to a picture, e.g., by an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a generalized cubemap projection SEI message with gcmp_cancel_flag equal to 0 being present in the CLVS that applies to the picture, a sphere rotation SEI message with sphere_rotation_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture. Decoders shall ignore sphere rotation SEI messages with sphere_rotation_cancel_flag equal to 0 for pictures to which no omnidirectional video projection is indicated to apply.

sphere_rotation_reserved_zero_6bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for sphere_rotation_reserved_zero_6bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of sphere_rotation_reserved_zero_6bits.

yaw_rotation specifies the value of the yaw rotation angle, in units of 2^{-16} degrees. The value of yaw_rotation shall be in the range of $-180 * 2^{16}$ (i.e., −11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. When not present, the value of yaw_rotation is inferred to be equal to 0.

pitch_rotation specifies the value of the pitch rotation angle, in units of 2^{-16} degrees. The value of pitch_rotation shall be in the range of $-90 * 2^{16}$ (i.e., −5 898 240) to $90 * 2^{16}$ (i.e., 5 898 240), inclusive. When not present, the value of pitch_rotation is inferred to be equal to 0.

roll_rotation specifies the value of the roll rotation angle, in units of 2^{-16} degrees. The value of roll_rotation shall be in the range of $-180 * 2^{16}$ (i.e., −11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. When not present, the value of roll_rotation is inferred to be equal to 0.

8.15.5 Region-wise packing SEI message

8.15.5.1 Region-wise packing SEI message syntax

regionwise_packing(payloadSize) {	**Descriptor**
rwp_cancel_flag	u(1)
if(!rwp_cancel_flag) {	
rwp_persistence_flag	u(1)

rwp_constituent_picture_matching_flag	u(1)
rwp_reserved_zero_5bits	u(5)
rwp_num_packed_regions	u(8)
rwp_proj_picture_width	u(32)
rwp_proj_picture_height	u(32)
rwp_packed_picture_width	u(16)
rwp_packed_picture_height	u(16)
for(i = 0; i < rwp_num_packed_regions; i++) {	
rwp_reserved_zero_4bits[i]	u(4)
rwp_transform_type[i]	u(3)
rwp_guard_band_flag[i]	u(1)
rwp_proj_region_width[i]	u(32)
rwp_proj_region_height[i]	u(32)
rwp_proj_region_top[i]	u(32)
rwp_proj_region_left[i]	u(32)
rwp_packed_region_width[i]	u(16)
rwp_packed_region_height[i]	u(16)
rwp_packed_region_top[i]	u(16)
rwp_packed_region_left[i]	u(16)
if(rwp_guard_band_flag[i]) {	
rwp_left_guard_band_width[i]	u(8)
rwp_right_guard_band_width[i]	u(8)
rwp_top_guard_band_height[i]	u(8)
rwp_bottom_guard_band_height[i]	u(8)
rwp_guard_band_not_used_for_pred_flag[i]	u(1)
for(j = 0; j < 4; j++)	
rwp_guard_band_type[i][j]	u(3)
rwp_guard_band_reserved_zero_3bits[i]	u(3)
}	
}	
}	
}	

8.15.5.2 Region-wise packing SEI message semantics

The RWP SEI message provides information to enable remapping of the colour samples of the cropped decoded pictures onto projected pictures as well as information on the location and size of the guard bands, if any.

Use of this SEI message requires the definition of the following variable:

– A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.

rwp_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous RWP SEI message in output order. rwp_cancel_flag equal to 0 indicates that RWP information follows.

rwp_persistence_flag specifies the persistence of the RWP SEI message for the current layer.

rwp_persistence_flag equal to 0 specifies that the RWP SEI message applies to the current decoded picture only.

rwp_persistence_flag equal to 1 specifies that the RWP SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a RWP SEI message is output that follows the current picture in output order.

When no omnidirectional video projection is indicated to apply to a picture, e.g., by an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a generalized cubemap projection SEI message with gcmp_cancel_flag equal to 0 being present in the CLVS that applies to the current picture, a RWP SEI message with rwp_cancel_flag equal to 0 shall not be present in the CLVS that applies to the picture. Decoders shall ignore RWP SEI messages with rwp_cancel_flag equal to 0 for pictures to which no omnidirectional video projection is indicated to apply.

When an equirectangular projection SEI message with erp_cancel_flag equal to 0 and erp_guard_band_flag equal to 1 is present in the CLVS that applies to the current picture, a RWP SEI message with rwp_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture.

When a generalized cubemap projection SEI message with gmcp_cancel_flag equal to 0 is present in the CLVS that applies to the current picture and precedes the RWP SEI message in decoding order, a RWP SEI message with rwp_cancel_flag equal to 0 shall not be present in the CLVS that applies to the current picture unless all the following conditions are true for the generalized cubemap projection SEI message:

– The value of gcmp_packing_type is equal to 2;

– The values of gcmp_face_index[i] for i from 0 to 5, inclusive, are equal to 5, 0, 4, 3, 1 and 2, respectively;

– The value of gcmp_face_rotation[i] is equal to 0 for each value of i in the range of 0 to 5, inclusive;

– The value of gcmp_guard_band_flag is equal to 0.

For the frame packing arrangement scheme indicated by a frame packing arrangement SEI message that applies to the current picture, if a RWP SEI message with rwp_cancel_flag equal to 0 is present that applies to the current picture, the frame packing arrangement scheme applies to the projected picture, otherwise, the frame packing arrangement scheme applies to the cropped decoded picture.

If a frame packing arrangement SEI message with fp_arrangement_cancel_flag equal to 0, fp_arrangement_type equal to 3, 4, or 5, and fp_quincunx_sampling_flag equal to 0 is not present that applies to the current picture, the variables StereoFlag, TopBottomFlag, SideBySideFlag, and TempInterleavingFlag are all set equal to 0, the variables HorDiv1 and VerDiv1 are both set equal to 1. Otherwise the following applies:

– StereoFlag is set equal to 1.

– When the fp_arrangement_type is equal to 3, SideBySideFlag is set equal to 1, TopBottomFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 2 and VerDiv1 is set equal to 1.

– When the fp_arrangement_type is equal to 4, TopBottomFlag is set equal to 1, SideBySideFlag and TempInterleavingFlag are both set equal to 0, HorDiv1 is set equal to 1 and VerDiv1 is set equal to 2.

– When the fp_arrangement_type is equal to 5, TempInterleavingFlag is set equal to 1, TopBottomFlag and SideBySideFlag are both set equal to 0, HorDiv1 and VerDiv1 are both set equal to 1.

rwp_constituent_picture_matching_flag equal to 1 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply individually to each constituent picture and that the packed picture and the projected picture have the same stereoscopic frame packing format indicated by the frame packing arrangement SEI message. rwp_constituent_picture_matching_flag equal to 0 specifies that the projected region information, packed region information, and guard band region information in this SEI message apply to the projected picture.

When either of the following conditions is true, the value of rwp_constituent_picture_matching_flag shall be equal to 0:

– StereoFlag is equal to 0.

– StereoFlag is equal to 1 and fp_arrangement_type is equal to 5.

rwp_reserved_zero_5bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_reserved_zero_56bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_reserved_zero_5bits[i].

rwp_num_packed_regions specifies the number of packed regions when rwp_constituent_picture_matching_flag is equal to 0. The value of rwp_num_packed_regions shall be greater than 0. When rwp_constituent_picture_matching_flag is equal to 1, the total number of packed regions is equal to rwp_num_packed_regions * 2, and the information in each entry of the loop of rwp_num_packed_regions entries applies to each constituent picture of the projected picture and the packed picture.

rwp_proj_picture_width and **rwp_proj_picture_height** specify the width and height, respectively, of the projected picture, in relative projected picture sample units.

NOTE 1 – Relative project picture sample unit is the unit used for the width or height of a projected picture or projected region. When a projected picture is a region-wise packed picture (i.e., there is a one-to-one mapping between the projected picture samples and the region-wise packed picture samples and a relative project picture sample unit is equivalent to a relative region-wise packed picture sample unit), rwp_proj_picture_width and rwp_proj_picture_height would have such values that rwp_proj_picture_width is an integer multiple of cropPicWidth and rwp_proj_picture_height is an integer multiple of cropPicHeight, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture, in units of luma samples.

The values of rwp_proj_picture_width and rwp_proj_picture_height shall both be greater than 0.

rwp_packed_picture_width and **rwp_packed_picture_height** specify the width and height, respectively, of the packed picture, in relative region-wise packed picture sample units.

The values of rwp_packed_picture_width and rwp_packed_picture_height shall both be greater than 0.

It is a requirement of bitstream conformance that rwp_packed_picture_width and rwp_packed_picture_height shall have such values that rwp_packed_picture_width is an integer multiple of cropPicWidth and rwp_packed_picture_height is an integer multiple of cropPicHeight, where cropPicWidth and cropPicHeight are the width and height, respectively, of the cropped decoded picture, in units of luma samples.

rwp_reserved_zero_4bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_reserved_zero_4bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_reserved_zero_4bits[i].

rwp_transform_type[i] specifies the rotation and mirroring to be applied to the i-th packed region to remap to the i-th projected region. When rwp_transform_type[i] specifies both rotation and mirroring, rotation applies before mirroring. The values of rwp_transform_type[i] are specified in Table 13.

Table 13 – rwp_transform_type[i] values

Value	Description
0	no transform
1	mirroring horizontally
2	rotation by 180 degrees (anticlockwise)
3	rotation by 180 degrees (anticlockwise) before mirroring horizontally
4	rotation by 90 degrees (anticlockwise) before mirroring horizontally
5	rotation by 90 degrees (anticlockwise)
6	rotation by 270 degrees (anticlockwise) before mirroring horizontally
7	rotation by 270 degrees (anticlockwise)

rwp_guard_band_flag[i] equal to 0 specifies that the i-th packed region does not have a guard band. rwp_guard_band_flag[i] equal to 1 specifies that the i-th packed region has a guard band.

rwp_proj_region_width[i], **rwp_proj_region_height**[i], **rwp_proj_region_top**[i] and **rwp_proj_region_left**[i] specify the width, height, top sample row, and the left-most sample column, respectively, of the i-th projected region, either within the projected picture (when rwp_constituent_picture_matching_flag is equal to 0) or within the constituent picture of the projected picture (when rwp_constituent_picture_matching_flag is equal to 1).

rwp_proj_region_width[i], rwp_proj_region_height[i], rwp_proj_region_top[i], and rwp_proj_region_left[i] are indicated in relative projected picture sample units.

NOTE 2 – Two projected regions could partially or entirely overlap with each other.

rwp_packed_region_width[i], **rwp_packed_region_height**[i], **rwp_packed_region_top**[i], and **rwp_packed_region_left**[i] specify the width, height, the top luma sample row, and the left-most luma sample column, respectively, of the packed region, either within the region-wise packed picture (when rwp_constituent_picture_matching_flag is equal to 0) or within each constituent picture of the region-wise packed picture (when rwp_constituent_picture_matching_flag is equal to 1).

rwp_packed_region_width[i], rwp_packed_region_height[i], rwp_packed_region_top[i], and rwp_packed_region_left[i] are indicated in relative region-wise packed picture sample units. rwp_packed_region_width[i], rwp_packed_region_height[i], rwp_packed_region_top[i], and rwp_packed_region_left[i] shall represent integer horizontal and vertical coordinates of luma sample units within the cropped decoded pictures.

NOTE 3 – Two packed regions could partially or entirely overlap with each other.

rwp_left_guard_band_width[i] specifies the width of the guard band on the left side of the i-th packed region in relative region-wise packed picture sample units. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), rwp_left_guard_band_width[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_right_guard_band_width[i] specifies the width of the guard band on the right side of the i-th packed region in relative region-wise packed picture sample units. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), rwp_right_guard_band_width[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_top_guard_band_height[i] specifies the height of the guard band above the i-th packed region in relative region-wise packed picture sample units. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), rwp_top_guard_band_height[i] shall correspond to an even number of luma samples within the cropped decoded picture.

rwp_bottom_guard_band_height[i] specifies the height of the guard band below the i-th packed region in relative region-wise packed picture sample units. When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), rwp_bottom_guard_band_height[i] shall correspond to an even number of luma samples within the cropped decoded picture.

When rwp_guard_band_flag[i] is equal to 1, rwp_left_guard_band_width[i], rwp_right_guard_band_width[i], rwp_top_guard_band_height[i], or rwp_bottom_guard_band_height[i] shall be greater than 0.

The i-th packed region as specified by this SEI message shall not overlap with any other packed region specified by the same SEI message or any guard band specified by the same SEI message.

The guard bands associated with the i-th packed region, if any, as specified by this SEI message shall not overlap with any packed region specified by the same SEI message or any other guard bands specified by the same SEI message.

rwp_guard_band_not_used_for_pred_flag[i] equal to 0 specifies that the guard bands might or might not be used in the inter prediction process. rwp_guard_band_not_used_for_pred_flag[i] equal to 1 specifies that the sample values of the guard bands are not used in the inter prediction process.

NOTE 4 – When rwp_guard_band_not_used_for_pred_flag[i] is equal to 1, the sample values within guard bands in cropped decoded pictures could be rewritten even if the cropped decoded pictures were used as references for inter prediction of subsequent pictures to be decoded. For example, the content of a packed region could be seamlessly expanded to its guard band with decoded and re-projected samples of another packed region.

rwp_guard_band_type[i][j] indicates the type of the guard bands for the i-th packed region as follows, with j equal to 0, 1, 2, or 3 indicating that the semantics apply to the left, right, top, or bottom edge, respectively, of the packed region:

– rwp_guard_band_type[i][j] equal to 0 indicates that the content of the guard bands in relation to the content of the packed regions is unknown or unspecified or specified by other means not specified in this Specification. When rwp_guard_band_not_used_for_pred_flag[i] is equal to 0, rwp_guard_band_type[i][j] shall not be equal to 0.

– rwp_guard_band_type[i][j] equal to 1 indicates that the content of the guard bands suffices for interpolation of sample values at sub-pel sample fractional locations within the packed region and less than one sample outside of the boundary of the packed region.

  NOTE 5 – rwp_guard_band_type[i][j] equal to 1 could be used when the boundary samples of a packed region have been copied horizontally or vertically to the guard band.

– rwp_guard_band_type[i][j] equal to 2 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at quality that gradually changes from the picture quality of the packed region to that of the spherically adjacent packed region.

– rwp_guard_band_type[i][j] equal to 3 indicates that the content of the guard bands represents actual picture content that is spherically adjacent to the content in the packed region and is on the surface of the packed region at a similar picture quality as within the packed region.

– rwp_guard_band_type[i][j] values greater than 3 are reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value of rwp_guard_band_type[i][j] when the value is greater than 3 as equivalent to the value 0.

rwp_guard_band_reserved_zero_3bits[i] shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for rwp_guard_band_reserved_zero_3bits[i] are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of rwp_guard_band_reserved_zero_3bits[i].

The variables NumPackedRegions, PackedRegionLeft[n], PackedRegionTop[n], PackedRegionWidth[n], PackedRegionHeight[n], ProjRegionLeft[n], ProjRegionTop[n], ProjRegionWidth[n], ProjRegionHeight[n], and TransformType[n] are derived as follows:

- For n in the range of 0 to rwp_num_packed_regions − 1, inclusive, the following applies:
  - PackedRegionLeft[n] is set equal to rwp_packed_region_left[n].
  - PackedRegionTop[n] is set equal to rwp_packed_region_top[n].
  - PackedRegionWidth[n] is set equal to rwp_packed_region_width[n].
  - PackedRegionHeight[n] is set equal to rwp_packed_region_height[n].
  - ProjRegionLeft[n] is set equal to rwp_proj_region_left[n].
  - ProjRegionTop[n] is set equal to rwp_proj_region_top[n].
  - ProjRegionWidth[n] is set equal to rwp_proj_region_width[n].
  - ProjRegionHeight[n] is set equal to rwp_proj_region_height[n].
  - TransformType[n] is set equal to rwp_transform_type[n].
- If rwp_constituent_picture_matching_flag is equal to 0, the following applies:
  - NumPackedRegions is set equal to rwp_num_packed_regions.
- Otherwise (rwp_constituent_picture_matching_flag is equal to 1), the following applies:
  - NumPackedRegions is set equal to 2 * rwp_num_packed_regions.
  - When TopBottomFlag is equal to 1, the following applies:
    - o projLeftOffset and packedLeftOffset are both set equal to 0.
    - o projTopOffset is set equal to rwp_proj_picture_height / 2 and packedTopOffset is set equal to rwp_packed_picture_height / 2.
  - When SideBySideFlag is equal to 1, the following applies:
    - o projLeftOffset is set equal to rwp_proj_picture_width / 2 and packedLeftOffset is set equal to rwp_packed_picture_width / 2.
    - o projTopOffset and packedTopOffset are both set equal to 0.
  - For n in the range of NumPackedRegions / 2 to NumPackedRegions − 1, inclusive, the following applies:
    - o nIdx is set equal to n − NumPackedRegions / 2.
    - o PackedRegionLeft[n] is set equal to rwp_packed_region_left[nIdx] + packedLeftOffset.
    - o PackedRegionTop[n] is set equal to rwp_packed_region_top[nIdx] + packedTopOffset.
    - o PackedRegionWidth[n] is set equal to rwp_packed_region_width[nIdx].
    - o PackedRegionHeight[n] is set equal to rwp_packed_region_height[nIdx].
    - o ProjRegionLeft[n] is set equal to rwp_proj_region_left[nIdx] + projLeftOffset.
    - o ProjRegionTop[n] is set equal to rwp_proj_region_top[nIdx] + projTopOffset.
    - o ProjRegionWidth[n] is set equal to rwp_proj_region_width[nIdx].
    - o ProjRegionHeight[n] is set equal to rwp_proj_region_height[nIdx].
    - o TransformType[n] is set equal to rwp_transform_type[nIdx].

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of ProjRegionWidth[n], ProjRegionHeight[n], ProjRegionTop[n], and ProjRegionLeft[n] are constrained as follows:

- ProjRegionWidth[n] shall be in the range of 1 to rwp_proj_picture_width, inclusive.
- ProjRegionHeight[n] shall be in the range of 1 to rwp_proj_picture_height, inclusive.
- ProjRegionLeft[n] shall be in the range of 0 to rwp_proj_picture_width − 1, inclusive.
- ProjRegionTop[n] shall be in the range of 0 to rwp_proj_picture_height − 1, inclusive.

– If ProjRegionTop[n] is less than rwp_proj_picture_height / VerDiv1, the sum of ProjRegionTop[n] and ProjRegionHeight[n] shall be less than or equal to rwp_proj_picture_height / VerDiv1. Otherwise, the sum of ProjRegionTop[n] and ProjRegionHeight[n] shall be less than or equal to rwp_proj_picture_height / VerDiv1 * 2.

For each value of n in the range of 0 to NumPackedRegions − 1, inclusive, the values of PackedRegionWidth[n], PackedRegionHeight[n], PackedRegionTop[n], and PackedRegionLeft[n] are constrained as follows:

– PackedRegionWidth[n] shall be in the range of 1 to rwp_packed_picture_width, inclusive.

– ProjRegionHeight[n] shall be in the range of 1 to rwp_packed_picture_height, inclusive.

– PackedRegionLeft[n] shall be in the range of 0 to rwp_packed_picture_width − 1, inclusive.

– PackedRegionTop[n] shall be in the range of 0 to rwp_packed_picture_height − 1, inclusive.

– If PackedRegionLeft[n] is less than rwp_packed_picture_width / HorDiv1, the sum of PackedRegionLeft[n] and PackedRegionWidth[n] shall be less than or equal to rwp_packed_picture_width / HorDiv1. Otherwise, the sum of PackedRegionLeft[n] and PackedRegionWidth[n] shall be less than or equal to rwp_packed_picture_width / HorDiv1 * 2.

– If PackedRegionTop[n] is less than rwp_packed_picture_height / VerDiv1, the sum of PackedRegionTop[n] and PackedRegionHeight[n] shall be less than or equal to rwp_packed_picture_height / VerDiv1. Otherwise, the sum of PackedRegionTop[n] and PackedRegionHeight[n] shall be less than or equal to rwp_packed_picture_height / VerDiv1 * 2.

– When ChromaFormatIdc is equal to 1 (4:2:0 chroma format) or 2 (4:2:2 chroma format), PackedRegionLeft[n] shall correspond to an even horizontal coordinate value of luma sample units, and PackedRegionWidth[n] shall correspond to an even number of luma samples, both within the decoded picture.

– When ChromaFormatIdc is equal to 1 (4:2:0 chroma format), PackedRegionTop[n] shall correspond to an even vertical coordinate value of luma sample units, and ProjRegionHeight[n] shall correspond to an even number of luma samples, both within the decoded picture.

8.15.6 Omnidirectional viewport SEI message

8.15.6.1 Omnidirectional viewport SEI message syntax

omni_viewport(payloadSize) {	**Descriptor**
omni_viewport_id	u(10)
omni_viewport_cancel_flag	u(1)
if(!omni_viewport_cancel_flag) {	
omni_viewport_persistence_flag	u(1)
omni_viewport_cnt_minus1	u(4)
for(i = 0; i <= omni_viewport_cnt_minus1; i++) {	
omni_viewport_azimuth_centre[i]	i(32)
omni_viewport_elevation_centre[i]	i(32)
omni_viewport_tilt_centre[i]	i(32)
omni_viewport_hor_range[i]	u(32)
omni_viewport_ver_range[i]	u(32)
}	
}	
}	

8.15.6.2 Omnidirectional viewport SEI message semantics

The omnidirectional viewport SEI message specifies the coordinates of one or more regions of spherical-coordinate geometry, bounded by four great circles, corresponding to viewports recommended for display when the user does not have control of the viewing orientation or has released control of the viewing orientation.

When an effectively applicable frame packing arrangement SEI message, as specified in clause 8.15.2.2 or clause 8.15.3.2, that applies to the picture is present, the information indicated by the omnidirectional viewport SEI message applies to both views.

omni_viewport_id contains an identifying number that may be used to identify the purpose of the one or more recommended viewport regions.

omni_viewport_id equal to 0 indicates that the recommended viewports are per "director's cut", i.e., a viewport suggested according to the creative intent of the content author or content provider. omni_viewport_id equal to 1 indicates that the recommended viewports are selected based on measurements of viewing statistics.

Values of omni_viewport_id from 2 to 511, inclusive, may be used as determined by the application. Values of omni_viewport_id from 512 to 1023 are reserved for future use by ITU-T | ISO/IEC. Decoders encountering a value of omni_viewport_id in the range of 512 to 1023, inclusive, shall ignore it.

omni_viewport_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous omnidirectional viewport SEI message in output order. omni_viewport_cancel_flag equal to 0 indicates that omnidirectional viewport information follows.

omni_viewport_persistence_flag specifies the persistence of the omnidirectional viewport SEI message for the current layer.

omni_viewport_persistence_flag equal to 0 specifies that the omnidirectional viewport SEI message applies to the current decoded picture only.

omni_viewport_persistence_flag equal to 1 specifies that the omnidirectional viewport SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.
– The bitstream ends.
– A picture in the current layer in an AU associated with an omnidirectional viewport SEI message is output that follows the current picture in output order.

When no omnidirectional video projection is indicated to apply to a picture, e.g., by an equirectangular projection SEI message with erp_cancel_flag equal to 0 or a generalized cubemap projection SEI message with gcmp_cancel_flag equal to 0 being present in the CLVS that applies to the current picture, an omnidirectional viewport SEI message with omni_viewport_cancel_flag equal to 0 shall not be present in the CLVS that applies to the picture. Decoders shall ignore omnidirectional viewport SEI messages with omni_viewport_cancel_flag equal to 0 for pictures to which no omnidirectional video projection is indicated to apply.

omni_viewport_cnt_minus1 plus 1 specifies the number of recommended viewport regions that are indicated by the SEI message.

When omni_viewport_cnt_minus1 is greater than 0 and there is no information provided by external means not specified in this Specification on which recommended viewport is suggested to be displayed, the following applies:

– When omni_viewport_id is equal to 0 or 1, the 0-th recommended viewport is suggested to be displayed when the user does not have control of the viewing orientation or has released control of the viewing orientation.

– When omni_viewport_id is equal to 0, between any two recommended viewports per director's cut, the i-th recommended viewport has higher priority than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th recommended viewport per director's cut has the highest priority.

– When omni_viewport_id is equal to 1, between any two recommended viewports, the i-th recommended viewport has higher popularity, among some selection of candidate viewports, than the j-th recommended viewport for any values of i and j when i is less than j. The 0-th most-viewed recommended viewport has the highest popularity. The selection of the candidate viewports is outside the scope of this Specification.

omni_viewport_azimuth_centre[i] and **omni_viewport_elevation_centre**[i] indicate the centre of the i-th recommended viewport region, in units of 2^{-16} degrees relative to the global coordinate axes. The value of omni_viewport_azimuth_centre[i] shall be in the range of $-180 * 2^{16}$ (i.e., −11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive. The value of omni_viewport_elevation_centre[i] shall be in the range of $-90 * 2^{16}$ (i.e., −5 898 240) to $90 * 2^{16}$ (i.e., 5 898 240), inclusive.

omni_viewport_tilt_centre[i] indicates the tilt angle of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_tilt_centre[i] shall be in the range of $-180 * 2^{16}$ (i.e., −11 796 480) to $180 * 2^{16} - 1$ (i.e., 11 796 479), inclusive.

omni_viewport_hor_range[i] indicates the azimuth range of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_hor_range[i] shall be in the range of 1 to $360 * 2^{16}$ (i.e., 23 592 960), inclusive.

omni_viewport_ver_range[i] indicates the elevation range of the i-th recommended viewport region, in units of 2^{-16} degrees. The value of omni_viewport_ver_range[i] shall be in the range of 1 to 180 * 2^{16} (i.e., 11 796 480), inclusive.

8.16 Frame-field information SEI message

8.16.1 Frame-field information SEI message syntax

frame_field_info(payloadSize) {	**Descriptor**
ffi_field_pic_flag	u(1)
if(ffi_field_pic_flag) {	
ffi_bottom_field_flag	u(1)
ffi_pairing_indicated_flag	u(1)
if(ffi_pairing_indicated_flag)	
ffi_paired_with_next_field_flag	u(1)
} else {	
ffi_display_fields_from_frame_flag	u(1)
if(ffi_display_fields_from_frame_flag)	
ffi_top_field_first_flag	u(1)
ffi_display_elemental_periods_minus1	u(8)
}	
ffi_source_scan_type	u(2)
ffi_duplicate_flag	u(1)
}	

8.16.2 Frame-field information SEI message semantics

The frame-field information SEI message may be used to indicate how the associated picture should be displayed (although this is merely a suggestion rather than a prescription, as the display process is outside the scope of this Specification), the source scan type of the associated picture, and whether the associated picture is a duplicate of a previous picture, in output order, of the same layer.

Use of this SEI message requires the definition of the following variables:

– A fixed picture rate indicator associated with a temporal sublayer, denoted herein by FixedPicRateWithinCvsFlag, such that value 1 indicates that the temporal distance between the display times of consecutive pictures in output order is constrained and value 0 indicates no such constraint.

– A display elemental period indicator, denoted herein by DisplayElementalPeriods, that indicates the number of elemental picture period intervals that the current coded picture occupies for the display model.

ffi_field_pic_flag equal to 1 indicates that the display model considers the current picture as a field, and ffi_field_pic_flag equal to 0 indicates that the display model considers the current picture as a frame.

ffi_bottom_field_flag equal to 1, when present, indicates that the current picture is a bottom field (i.e., that the parity of the current picture is bottom). ffi_bottom_field_flag equal to 0 indicates that the current picture is a top field (i.e., that the parity of the current picture is top). The two parities, bottom and top, are considered as opposite parities.

ffi_pairing_indicated_flag equal to 1, when present, indicates that the current picture is considered paired with the next picture in output order or with the previous picture in output order as the two fields of a frame. ffi_pairing_indicated_flag equal to 0, when present, indicates that a pairing of the current picture with another picture to form a frame is not expressed.

ffi_paired_with_next_field_flag equal to 1, when present, indicates that the current picture is considered paired with the next picture as the two fields of a frame. ffi_paired_with_next_field_flag equal to 0, when present, indicates that the current picture is considered paired with the previous picture as the two fields of a frame.

When ffi_paired_with_next_field_flag is present, the following constraints shall apply

– If ffi_paired_with_next_field_flag is equal to 0, there shall be at least one picture in the CLVS that precedes the current picture in output order and the picture that precedes the current picture in output order shall have the opposite parity and ffi_pairing_indicated_flag equal to 1 and the value of ffi_paired_with_next_field_flag for that preceding picture in output order shall be equal to 1.

– Otherwise, there shall be at least one picture in the CLVS that follows the current picture in output order and the picture that follows the current picture in output order shall have the opposite parity and ffi_pairing_indicated_flag equal to 1 and the value of ffi_paired_with_next_field_flag for that following picture in output order shall be equal to 0.

ffi_display_fields_from_frame_flag equal to 1, when present, indicates that the display model operates by sequentially displaying the individual fields of the frame with alternating parity. ffi_display_fields_from_frame_flag equal to 0, when present, indicates that the display model operates by displaying the current picture as a complete frame.

ffi_top_field_first_flag equal to 1, when present, indicates that the first field of the frame that is displayed by the display model is the top field. ffi_top_field_first_flag equal to 0, when present, indicates that the first field of the frame that is displayed by the display model is the bottom field.

ffi_display_elemental_periods_minus1 plus 1, when present, indicates the number of elemental picture period intervals that the current coded picture or field occupies for the display model. The value of ffi_display_elemental_periods_minus1 shall be equal to DisplayElementalPeriods − 1.

The interpretation of combinations of ffi_field_pic_flag, FixedPicRateWithinCvsFlag, ffi_bottom_field_flag, ffi_display_fields_from_frame_flag, ffi_top_field_first_flag, and ffi_display_elemental_periods_minus1 (through DisplayElementalPeriods) is specified in Table 14, in which syntax elements that are not present are indicated by "–". Combinations of syntax elements that are not listed in Table 14 are reserved for future use by ITU-T | ISO/IEC and shall not be present in bitstreams conforming to this version of this Specification.

NOTE 1 – When FixedPicRateWithinCvsFlag is equal to 1, the indicated display times are constrained to account for time duration for a display model that follows the display patterns indicated by the values of the syntax elements of the frame-field information SEI message (although the display process is outside the scope of this Specification). Although the video decoder model might be specified to only output the entire cropped decoded picture, the modelled display behaviour sometimes includes other steps, such as the repeated display of a frame for multiple time intervals when ffi_display_fields_from_frame_flag is equal to 0 or the sequential display of the individual fields of a frame when ffi_display_fields_from_frame_flag is equal to 1.

NOTE 2 – Frame doubling can be used to facilitate the display, for example, of 25 Hz progressive-scan video on a 50 Hz progressive-scan display or 30 Hz progressive-scan video on a 60 Hz progressive-scan display. Using frame doubling and frame tripling in alternating combination on every other frame could be used to facilitate the display of 24 Hz progressive-scan video on a 60 Hz progressive-scan display.

Table 14 – Interpretation of frame-field information syntax elements

ffi_field_pic_flag	FixedPicRateWithinCvsFlag	ffi_bottom_field_flag	ffi_display_fields_from_frame_flag	ffi_top_field_first_flag	DisplayElementalPeriods		Indicated display of the picture by the display model
0	0	–	0	–	1		(progressive) Frame
		–	1	0	2		Bottom field, top field, in that order
		–	1	1	2		Top field, bottom field, in that order
		–	1	0	3		Bottom field, top field, bottom field repeated, in that order
		–	1	1	3		Top field, bottom field, top field repeated, in that order
	1	–	0	–	n		(progressive) Frame displayed for n elemental periods of time
		–	1	0	2		Bottom field, top field, in that order, each displayed for 1 elemental period of time
		–	1	1	2		Top field, bottom field, in that order, each displayed for 1 elemental period of time
		–	1	0	3		Bottom field, top field, bottom field repeated, in that order, each displayed for 1 elemental period of time
		–	1	1	3		Top field, bottom field, top field repeated, in that order, each displayed for 1 elemental period of time
1	0	0	–	–	1		Top field
		1	–	–	1		Bottom field
	1	0	–	–	1		Top field displayed for 1 elemental period of time
		1	–	–	–		Bottom field displayed for 1 elemental period of time

ffi_source_scan_type equal to 1 indicates that the source scan type of the associated picture should be interpreted as progressive. ffi_source_scan_type equal to 0 indicates that the source scan type of the associated picture should be interpreted as interlaced. ffi_source_scan_type equal to 2 indicates that the source scan type of the associated picture is unknown or unspecified or specified by other means not specified in this Specification. ffi_source_scan_type equal to 3 is reserved for future use by ITU-T | ISO/IEC and shall not be present in bitstreams conforming to this version of this Specification. Decoders conforming to this version of this Specification shall interpret the value 3 for ffi_source_scan_type as equivalent to the value 2.

ffi_duplicate_flag equal to 1 indicates that the current picture is indicated to be a duplicate of a previous picture in output order. ffi_duplicate_flag equal to 0 indicates that the current picture is not indicated to be a duplicate of a previous picture in output order.

NOTE 3 – The ffi_duplicate_flag could be used to mark coded pictures known to have originated from a repetition process such as "3:2 pull-down" or other such duplication and picture rate interpolation methods. This flag would commonly be used when a video feed is encoded as a field sequence in a "transport pass-through" fashion, with known duplicate pictures tagged by setting ffi_duplicate_flag equal to 1.

NOTE 4 – When ffi_field_pic_flag is equal to 1 and ffi_duplicate_flag is equal to 1, this could be interpreted as an indication that the AU contains a field that duplicates the content of the previous field in output order with the same parity as the current field.

8.17 Sample aspect ratio information SEI message

8.17.1 Sample aspect ratio information SEI message syntax

sample_aspect_ratio_info(payloadSize) {	**Descriptor**
sari_cancel_flag	u(1)
if(!sari_cancel_flag) {	
sari_persistence_flag	u(1)
sari_aspect_ratio_idc	u(8)
if(sari_aspect_ratio_idc = = 255) {	
sari_sar_width	u(16)
sari_sar_height	u(16)
}	
}	
}	

8.17.2 Sample aspect ratio information SEI message semantics

The SARI SEI message provides information about the sample aspect ratio of the samples of the associated decoded pictures. When vui_aspect_ratio_constant_flag is equal to 1, there shall be no SARI SEI messages present in the CLVS.

sari_cancel_flag equal to 1 indicates that the SARI SEI message cancels the persistence of any previous SARI SEI messages in output order that applies to the current layer. sari_cancel_flag equal to 0 indicates that SARI follows.

sari_persistence_flag specifies the persistence of the SARI SEI message for the current layer.

sari_persistence_flag equal to 0 specifies that the SARI applies to the current decoded picture only.

sar_persistence_flag equal to 1 specifies that the SARI SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.
– The bitstream ends.
– A picture in the current layer in an AU associated with a SARI SEI message is output that follows the current picture in output order.

sari_aspect_ratio_idc, when not equal to 255, indicates the sample aspect ratio of the luma samples of the decoded output picture, with the same semantics as specified for the SampleAspectRatio parameter in Rec. ITU-T H.273 | ISO/IEC 23091-2. When the sari_aspect_ratio_idc syntax element is not present, the value of sari_aspect_ratio_idc is inferred to be equal to 0. Values of sari_aspect_ratio_idc that are specified as reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 shall not be present in bitstreams conforming to this version of this Specification. Decoders shall interpret values of sari_aspect_ratio_idc that are reserved for future use in Rec. ITU-T H.273 | ISO/IEC 23091-2 as equivalent to the value 0.

sari_sar_width, when present, indicates the horizontal size of the sample aspect ratio (in an arbitrary unit).

sari_sar_height, when present, indicates the vertical size of the sample aspect ratio (in the same arbitrary unit as sari_sar_width).

When present, sari_sar_width and sari_sar_height shall be relatively prime or equal to 0. When sari_aspect_ratio_idc is equal to 0 or sari_sar_width is equal to 0 or sari_sar_height is equal to 0, the sample aspect ratio is unknown or unspecified or specified by other means not specified in this Specification.

8.18 Annotated regions SEI message

8.18.1 Annotated regions SEI message syntax

annotated_regions(payloadSize) {	**Descriptor**
ar_cancel_flag	u(1)
if(!ar_cancel_flag) {	
ar_not_optimized_for_viewing_flag	u(1)
ar_true_motion_flag	u(1)
ar_occluded_object_flag	u(1)
ar_partial_object_flag_present_flag	u(1)
ar_object_label_present_flag	u(1)
ar_object_confidence_info_present_flag	u(1)
if(ar_object_confidence_info_present_flag)	
ar_object_confidence_length_minus1	u(4)
if(ar_object_label_present_flag) {	
ar_object_label_language_present_flag	u(1)
if(ar_object_label_language_present_flag) {	
while(!byte_aligned( ))	
ar_bit_equal_to_zero /* equal to 0 */	f(1)
ar_object_label_language	st(v)
}	
ar_num_label_updates	ue(v)
for(i = 0; i < ar_num_label_updates; i++) {	
ar_label_idx[i]	ue(v)
ar_label_cancel_flag	u(1)
LabelAssigned[ar_label_idx[i]] = !ar_label_cancel_flag	
if(!ar_label_cancel_flag) {	
while(!byte_aligned( ))	
ar_bit_equal_to_zero /* equal to 0 */	f(1)
ar_label[ar_label_idx[i]]	st(v)
}	
}	
}	
ar_num_object_updates	ue(v)
for(i = 0; i < ar_num_object_updates; i++) {	
ar_object_idx[i]	ue(v)
ar_object_cancel_flag	u(1)
ObjectTracked[ar_object_idx[i]] = !ar_object_cancel_flag	
if(!ar_object_cancel_flag) {	
if(ar_object_label_present_flag) {	
ar_object_label_update_flag	u(1)
if(ar_object_label_update_flag)	
ar_object_label_idx[ar_object_idx[i]]	ue(v)
}	
ar_bounding_box_update_flag	u(1)
if(ar_bounding_box_update_flag) {	
ar_bounding_box_cancel_flag	u(1)

ObjectBoundingBoxAvail[ar_object_idx[i]] = !ar_bounding_box_cancel_flag	
if(!ar_bounding_box_cancel_flag) {	
ar_bounding_box_top[ar_object_idx[i]]	u(16)
ar_bounding_box_left[ar_object_idx[i]]	u(16)
ar_bounding_box_width[ar_object_idx[i]]	u(16)
ar_bounding_box_height[ar_object_idx[i]]	u(16)
if(ar_partial_object_flag_present_flag)	
ar_partial_object_flag[ar_object_idx[i]]	u(1)
if(ar_object_confidence_info_present_flag)	
ar_object_confidence[ar_object_idx[i]]	u(v)
}	
}	
}	
}	
}	

8.18.2 Annotated regions SEI message semantics

The annotated regions SEI message carries parameters that identify annotated regions using bounding boxes representing the size and location of identified objects.

Use of this SEI message requires the definition of the following variables:

- A cropped picture width and picture height in units of luma samples, denoted herein by CroppedWidth and CroppedHeight, respectively.
- A conformance cropping window left offset, ConfWinLeftOffset
- A conformance cropping window top offset, ConfWinTopOffset
- A chroma format indicator, denoted herein by ChromaFormatIdc, as described in clause 7.3.

The variables SubWidthC and SubHeightC are derived from ChromaFormatIdc as specified by Table 2.

ar_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous annotated regions SEI message that is associated with one or more layers to which the annotated regions SEI message applies. ar_cancel_flag equal to 0 indicates that annotated regions information follows.

When ar_cancel_flag equal to 1 or a new CVS of the current layer begins, the variables LabelAssigned[i], ObjectTracked[i], and ObjectBoundingBoxAvail are set equal to 0 for i in the range of 0 to 255, inclusive.

ar_not_optimized_for_viewing_flag equal to 1 indicates that the decoded pictures that the annotated regions SEI message applies to are not optimized for user viewing, but rather are optimized for some other purpose such as algorithmic object classification performance. ar_not_optimized_for_viewing_flag equal to 0 indicates that the decoded pictures that the annotated regions SEI message applies to may or may not be optimized for user viewing.

ar_true_motion_flag equal to 1 indicates that the motion information in the coded pictures that the annotated regions SEI message applies to was selected with a goal of accurately representing object motion for objects in the annotated regions. ar_true_motion_flag equal to 0 indicates that the motion information in the coded pictures that the annotated regions SEI message applies to may or may not be selected with a goal of accurately representing object motion for objects in the annotated regions.

ar_occluded_object_flag equal to 1 indicates that the ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]], and ar_bounding_box_height[ar_object_idx[i]] syntax elements represent the size and location of an object or a portion of an object that may not be visible or may be only partially visible within the cropped decoded picture. ar_occluded_object_flag equal to 0 indicates that the ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]], and ar_bounding_box_height[ar_object_idx[i]] syntax elements represent the size and location of an object that is entirely visible within the cropped decoded picture. It is a requirement of bitstream conformance that the value of ar_occluded_object_flag shall be the same for all annotated_regions( ) syntax structures within a CVS.

ar_partial_object_flag_present_flag equal to 1 indicates that ar_partial_object_flag[ar_object_idx[i]] syntax elements are present. ar_partial_object_flag_present_flag equal to 0 indicates that ar_partial_object_flag[ar_object_idx[i]] syntax elements are not present. It is a requirement of bitstream conformance that the value of ar_partial_object_flag_present_flag shall be the same for all annotated_regions( ) syntax structures within a CVS.

ar_object_label_present_flag equal to 1 indicates that label information corresponding to objects in the annotated regions is present. ar_object_label_present_flag equal to 0 indicates that label information corresponding to the objects in the annotated regions is not present.

ar_object_confidence_info_present_flag equal to 1 indicates that ar_object_confidence[ar_object_idx[i]] syntax elements are present. ar_object_confidence_info_present_flag equal to 0 indicates that ar_object_confidence[ar_object_idx[i]] syntax elements are not present. It is a requirement of bitstream conformance that the value of ar_object_confidence_present_flag shall be the same for all annotated_regions( ) syntax structures within a CVS.

ar_object_confidence_length_minus1 plus 1 specifies the length, in bits, of the ar_object_confidence[ar_object_idx[i]] syntax elements. It is a requirement of bitstream conformance that the value of ar_object_confidence_length_minus1 shall be the same for all annotated_regions( ) syntax structures within a CVS.

ar_object_label_language_present_flag equal to 1 indicates that the ar_object_label_language syntax element is present. ar_object_label_language_present_flag equal to 0 indicates that the ar_object_label_language syntax element is not present.

ar_bit_equal_to_zero shall be equal to zero.

ar_object_label_language contains a language tag as specified by IETF RFC 5646 followed by a null termination byte equal to 0x00. The length of the ar_object_label_language syntax element shall be less than or equal to 255 bytes, not including the null termination byte. When not present, the language of the label is unspecified.

ar_num_label_updates indicates the total number of labels associated with the annotated regions that are signalled. The value of ar_num_label_updates shall be in the range of 0 to 255, inclusive.

ar_label_idx[i] indicates the index of the signalled label. The value of ar_label_idx[i] shall be in the range of 0 to 255, inclusive.

ar_label_cancel_flag equal to 1 cancels the persistence scope of the ar_label_idx[i]-th label. ar_label_cancel_flag equal to 0 indicates that the ar_label_idx[i]-th label is assigned a signalled value.

LabelAssigned[ar_label_idx[i]] equal to 1 indicates that the ar_label_idx[i]-th label is assigned. LabelAssigned[ar_label_idx[i]] equal to 0 indicates that the ar_label_idx[i]-th label is not assigned.

ar_label[ar_label_idx[i]] specifies the contents of the ar_label_idx[i] –th label. The length of the ar_label[ar_label_idx[i]] syntax element shall be less than or equal to 255 bytes, not including the null termination byte.

ar_num_object_updates indicates the number of object updates to be signalled. ar_num_object_updates shall be in the range of 0 to 255, inclusive.

ar_object_idx[i] is the index of the object parameters to be signalled. ar_object_idx[i] shall be in the range of 0 to 255, inclusive.

ar_object_cancel_flag equal to 1 cancels the persistence scope of the ar_object_idx[i]-th object. ar_object_cancel_flag equal to 0 indicates that parameters associated with the ar_object_idx[i]-th object are signalled.

ObjectTracked[ar_object_idx[i]] equal to 1 indicates that the object_idx[i]-th object is tracked. ObjectTracked[ar_object_idx[i]] equal to 0 indicates that the object_idx[i]-th object is not tracked.

ar_object_label_update_flag equal to 1 indicates that an object label is signalled. ar_object_label_update_flag equal to 0 indicates that an object label is not signalled.

ar_object_label_idx[ar_object_idx[i]] indicates the index of the label corresponding to the ar_object_idx[i]-th object. When ar_object_label_idx[ar_object_idx[i]] is not present, its value is inferred from a previous annotated regions SEI message in output order in the same CVS, if any. The value of ar_object_label_idx[ar_object_idx[i]] shall be in the range of 0 to 255, inclusive.

ar_bounding_box_update_flag equal to 1 indicates that object bounding box parameters are signalled. ar_bounding_box_update_flag equal to 0 indicates that object bounding box parameters are not signalled.

ar_bounding_box_cancel_flag equal to 1 cancels the persistence scope of the ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]], ar_bounding_box_height[ar_object_idx[i]].

ar_partial_object_flag[ar_object_idx[i]], and ar_object_confidence[ar_object_idx[i]]. ar_bounding_box_cancel_flag equal to 0 indicates that ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]] ar_bounding_box_height[ar_object_idx[i]] ar_partial_object_flag[ar_object_idx[i]], and ar_object_confidence[ar_object_idx[i]] syntax elements are signalled.

ObjectBoundingBoxAvail[ar_object_idx[i]] equal to 1 indicates that the bounding box information of the object_idx[i]-th object is signalled. ObjectBoundingBoxAvail[ar_object_idx[i]] equal to 0 indicates that the bounding box information of the object_idx[i]-th object is not signalled.

ar_bounding_box_top[ar_object_idx[i]], **ar_bounding_box_left**[ar_object_idx[i]], **ar_bounding_box_width**[ar_object_idx[i]], and **ar_bounding_box_height**[ar_object_idx[i]] specify the coordinates of the top-left corner and the width and height, respectively, of the bounding box of the ar_object_idx[i]-th object in the cropped decoded picture, relative to the conformance cropping window specified by the active SPS.

The value of ar_bounding_box_left[ar_object_idx[i]] shall be in the range of 0 to CroppedWidth / SubWidthC − 1, inclusive.

The value of ar_bounding_box_top[ar_object_idx[i]] shall be in the range of 0 to CroppedHeight / SubHeightC − 1, inclusive.

The value of ar_bounding_box_width[ar_object_idx[i]] shall be in the range of 0 to CroppedWidth / SubWidthC − ar_bounding_box_left[ar_object_idx[i]], inclusive.

The value of ar_bounding_box_height[ar_object_idx[i]] shall be in the range of 0 to CroppedHeight / SubHeightC − ar_bounding_box_top[ar_object_idx[i]], inclusive.

The identified object rectangle contains the luma samples with horizontal picture coordinates from SubWidthC * (ConfWinLeftOffset + ar_bounding_box_left[ar_object_idx[i]]) to SubWidthC * (ConfWinLeftOffset + ar_bounding_box_left[ar_object_idx[i]] + ar_bounding_box_width[ar_object_idx[i]]) − 1, inclusive, and vertical picture coordinates from SubHeightC * (ConfWinTopOffset + ar_bounding_box_top[ar_object_idx[i]]) to SubHeightC * (ConfWinTopOffset + ar_bounding_box_top[ar_object_idx[i]] + ar_bounding_box_height[ar_object_idx[i]]) − 1, inclusive.

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.

The values of ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]] and ar_bounding_box_height[ar_object_idx[i]] persist in output order within the CVS for each value of ar_object_idx[i]. When not present, the values of ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]] or ar_bounding_box_height[ar_object_idx[i]] are inferred from a previous annotated regions SEI message in output order in the CVS, if any.

ar_partial_object_flag[ar_object_idx[i]] equal to 1 indicates that the ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]] and ar_bounding_box_height[ar_object_idx[i]] syntax elements represent the size and location of an object that is only partially visible within the cropped decoded picture. ar_partial_object_flag[ar_object_idx[i]] equal to 0 indicates that the ar_bounding_box_top[ar_object_idx[i]], ar_bounding_box_left[ar_object_idx[i]], ar_bounding_box_width[ar_object_idx[i]] and ar_bounding_box_height[ar_object_idx[i]] syntax elements represent the size and location of an object that may or may not be only partially visible within the cropped decoded picture. When not present, the value of ar_partial_object_flag[ar_object_idx[i]] is inferred from a previous annotated regions SEI message in output order in the CVS, if any.

ar_object_confidence[ar_object_idx[i]] indicates the degree of confidence associated with the ar_object_idx[i]-th object, in units of $2^{-(\text{ar\_object\_confidence\_length\_minus1} + 1)}$, such that a higher value of ar_object_confidence[ar_object_idx[i]] indicates a higher degree of confidence. The length of the ar_object_confidence[ar_object_idx[i]] syntax element is ar_object_confidence_length_minus1 + 1 bits. When not present, the value of_object_confidence[ar_object_idx[i]] is inferred from a previous annotated regions SEI message in output order in the CVS, if any.

8.19 Scalability dimension information SEI message

8.19.1 Scalability dimension information SEI message syntax

scalability_dimension_info(payloadSize) {	**Descriptor**
sdi_max_layers_minus1	u(6)
sdi_multiview_info_flag	u(1)
sdi_auxiliary_info_flag	u(1)
if(sdi_multiview_info_flag || sdi_auxiliary_info_flag) {	
if(sdi_multiview_info_flag)	
sdi_view_id_len_minus1	u(4)
for(i = 0; i <= sdi_max_layers_minus1; i++) {	
sdi_layer_id[i]	u(6)
if(sdi_multiview_info_flag)	
sdi_view_id_val[i]	u(v)
if(sdi_auxiliary_info_flag)	
sdi_aux_id[i]	u(8)
if(sdi_aux_id[i] > 0) {	
sdi_num_associated_primary_layers_minus1[i]	u(6)
for(j = 0; j <= sdi_num_associated_primary_layers_minus1[i]; j++)	
sdi_associated_primary_layer_idx[i][j]	u(6)
}	
}	
}	
}	
}	

8.19.2 Scalability dimension information SEI message semantics

The scalability dimension information (SDI) SEI message provides the SDI for each layer in the current CVS, i.e., the CVS containing the SDI SEI message, such as 1) when there may be multiple views, the view ID of each layer; and 2) when there may be auxiliary information (such as depth or alpha) carried by one or more layers, the auxiliary ID of each layer.

When an SDI SEI message is present in any AU of a CVS, an SDI SEI message shall be present for the first AU of the CVS. All SDI SEI messages in a CVS shall have the same content.

sdi_max_layers_minus1 plus 1 indicates the maximum number of layers in the current CVS.

sdi_multiview_info_flag equal to 1 indicates that the current CVS may have multiple views and the sdi_view_id_val[ ] syntax elements are present in the SDI SEI message. sdi_multiview_info_flag equal to 0 indicates that the current CVS does not have multiple views and the sdi_view_id_val[ ] syntax elements are not present in the SDI SEI message.

sdi_auxiliary_info_flag equal to 1 indicates that one or more layers in the current CVS may be auxiliary layers, which carry auxiliary information, and the sdi_aux_id[ ] syntax elements are present in the SDI SEI message. sdi_auxiliary_info_flag equal to 0 indicates that the current CVS does not have an auxilary layer and the sdi_aux_id[ ] syntax elements are not present in the SDI SEI message.

sdi_view_id_len_minus1 plus 1 specifies the length, in bits, of the sdi_view_id_val[i] syntax element.

sdi_layer_id[i] specifies the layer identifier of the i-th layer that may be present in the current CVS.

sdi_view_id_val[i] specifies the view identifier of the i-th layer in the current CVS. The length of the sdi_view_id_val[i] syntax element is sdi_view_id_len_minus1 + 1 bits.

The variable NumViews, specifying the number of views in the current CVS, and the list ViewId, specifying the view identifiers of the views in the current CVS, are derived as follows:

```
NumViews = 1
if( sdi_multiview_info_flag ) {
    ViewId[ 0 ] = sdi_view_id_val[ 0 ]
    for( i = 1; i  <=  sdi_max_layers_minus1; i++ ) {
        newViewFlag = 1
        for( j = 0; j < i; j++ )                                                    (47)
            if( sdi_view_id_val[ i ]  = =  sdi_view_id_val[ j ] )
                newViewFlag = 0
        if( newViewFlag ) {
            ViewId[ NumViews ] = sdi_view_id_val[ i ]
            NumViews++
        }
    }
}
```

sdi_aux_id[i] equal to 0 indicates that the i-th layer in the current CVS does not contain auxiliary pictures. sdi_aux_id[i] greater than 0 indicates the type of auxiliary pictures in the i-th layer in the current CVS as specified in Table 15. When sdi_auxiliary_info_flag is equal to 0, the value of sdi_aux_id[i] is inferred to be equal to 0.

Table 15 – Mapping of sdi_aux_id[i] to the type of auxiliary pictures

sdi_aux_id[i]	Name	Type of auxiliary pictures
1	AUX_ALPHA	Alpha plane
2	AUX_DEPTH	Depth picture
3..127		Reserved
128..159		Unspecified
160..255		Reserved

NOTE 1 – The interpretation of auxiliary pictures associated with sdi_aux_id[i] in the range of 128 to 159, inclusive, is specified through means other than the sdi_aux_id[i] value.

sdi_aux_id[i] shall be in the range of 0 to 2, inclusive, or 128 to 159, inclusive, for bitstreams conforming to this version of this Specification. Although the value of sdi_aux_id[i] shall be in the range of 0 to 2, inclusive, or 128 to 159, inclusive, in this version of this Specification, decoders shall also allow other values of sdi_aux_id[i] in the range of 0 to 255, inclusive.

If sdi_aux_id[i] is equal to 0, the i-th layer is referred to as a primary layer. Otherwise, the i-th layer is referred to as an auxiliary layer. When sdi_aux_id[i] is equal to 1, the i-th layer is also referred to as an alpha auxiliary layer. When sdi_aux_id[i] is equal to 2, the i-th layer is also referred to as a depth auxiliary layer.

sdi_num_associated_primary_layers_minus1[i] plus 1 specifies the number of associated primary layers of i-th layer, which is an auxiliary layer. The value of sdi_num_associated_primary_layers_minus1[i] shall be less than the total number of primary layers.

sdi_associated_primary_layer_idx[i][j] specifies the layer index of the j-th associated primary layer of the i-th layer, which is an auxiliary layer. The value of sdi_aux_id[sdi_associated_primary_layer_idx[i][j]] shall be equal to 0.

NOTE 23 – An auxiliary layer describes a property of and applies to its associated primary layers.

8.20 Multiview acquisition information SEI message

8.20.1 Multiview acquisition information SEI message syntax

multiview_acquisition_info(payloadSize) {	**Descriptor**
intrinsic_param_flag	u(1)
extrinsic_param_flag	u(1)
num_views_minus1	ue(v)
if(intrinsic_param_flag) {	
intrinsic_params_equal_flag	u(1)
prec_focal_length	ue(v)

prec_principal_point	ue(v)
prec_skew_factor	ue(v)
for(i = 0; i <= intrinsic_params_equal_flag ? 0 : num_views_minus1; i++) {	
sign_focal_length_x[i]	u(1)
exponent_focal_length_x[i]	u(6)
mantissa_focal_length_x[i]	u(v)
sign_focal_length_y[i]	u(1)
exponent_focal_length_y[i]	u(6)
mantissa_focal_length_y[i]	u(v)
sign_principal_point_x[i]	u(1)
exponent_principal_point_x[i]	u(6)
mantissa_principal_point_x[i]	u(v)
sign_principal_point_y[i]	u(1)
exponent_principal_point_y[i]	u(6)
mantissa_principal_point_y[i]	u(v)
sign_skew_factor[i]	u(1)
exponent_skew_factor[i]	u(6)
mantissa_skew_factor[i]	u(v)
}	
}	
if(extrinsic_param_flag) {	
prec_rotation_param	ue(v)
prec_translation_param	ue(v)
for(i = 0; i <= num_views_minus1; i++)	
for(j = 0; j < 3; j++) { /* row */	
for(k = 0; k < 3; k++) { /* column */	
sign_r[i][j][k]	u(1)
exponent_r[i][j][k]	u(6)
mantissa_r[i][j][k]	u(v)
}	
sign_t[i][j]	u(1)
exponent_t[i][j]	u(6)
mantissa_t[i][j]	u(v)
}	
}	
}	

8.20.2 Multiview acquisition information SEI message semantics

The multiview acquisition information (MAI) SEI message specifies various parameters of the acquisition environment for the layers that may be present in the current CVS, i.e., the CVS containing the MAI SEI message. Specifically, intrinsic and extrinsic camera parameters are specified. These parameters could be used for processing the decoded views prior to rendering on a 3D display.

When an MAI SEI message is present in any AU of a CVS, an MAI SEI message shall be present for the first AU of the CVS. All MAI SEI messages in a CVS shall have the same content.

When a CVS does not contain an SDI SEI message, the CVS shall not contain an MAI SEI message.

When an AU contains both an SDI SEI message and an MAI SEI message, the SDI SEI message shall precede the MAI SEI message in decoding order.

Some of the views for which the MAI is included in an MAI SEI message may not be present in the current CVS.

In the semantics below, syntax elements and variables with index i refer to the syntax elements and variables that apply to the i-th view in the current CVS specified by the SDI SEI message, i.e., the view with view identifier equal to ViewId[i].

The extrinsic camera parameters are specified according to a right-handed coordinate system, where the upper left corner of the image is the origin, i.e., the (0, 0) coordinate, with the other corners of the image having non-negative coordinates. With these specifications, a 3-dimensional world point, wP = [x y z] is mapped to a 2-dimensional camera point, cP[i] = [u v 1], for the i-th camera according to:

$$s * cP[i] = A[i] * R^{-1}[i] * (wP - T[i]) \quad (48)$$

where A[i] denotes the intrinsic camera parameter matrix, R^{-1}[i] denotes the inverse of the rotation matrix R[i], T[i] denotes the translation vector and s (a scalar value) is an arbitrary scale factor chosen to make the third coordinate of cP[i] equal to 1. The elements of A[i], R[i] and T[i] are determined according to the syntax elements signalled in this SEI message and as specified below.

intrinsic_param_flag equal to 1 indicates the presence of intrinsic camera parameters. intrinsic_param_flag equal to 0 indicates the absence of intrinsic camera parameters.

extrinsic_param_flag equal to 1 indicates the presence of extrinsic camera parameters. extrinsic_param_flag equal to 0 indicates the absence of extrinsic camera parameters.

num_views_minus1 plus 1 specifies the number of views for which the MAI is included in the MAI SEI message. The value of num_views_minus1 shall be equal to NumViews − 1.

intrinsic_params_equal_flag equal to 1 indicates that the intrinsic camera parameters are equal for all cameras and only one set of intrinsic camera parameters is present. intrinsic_params_equal_flag equal to 0 indicates that the intrinsic camera parameters are different for each camera and that a set of intrinsic camera parameters is present for each camera.

prec_focal_length specifies the exponent of the maximum allowable truncation error for focal_length_x[i] and focal_length_y[i] as given by $2^{-\text{prec\_focal\_length}}$. The value of prec_focal_length shall be in the range of 0 to 31, inclusive.

prec_principal_point specifies the exponent of the maximum allowable truncation error for principal_point_x[i] and principal_point_y[i] as given by $2^{-\text{prec\_principal\_point}}$. The value of prec_principal_point shall be in the range of 0 to 31, inclusive.

prec_skew_factor specifies the exponent of the maximum allowable truncation error for skew factor as given by $2^{-\text{prec\_skew\_factor}}$. The value of prec_skew_factor shall be in the range of 0 to 31, inclusive.

sign_focal_length_x[i] equal to 0 indicates that the sign of the focal length of the i-th camera in the horizontal direction is positive. sign_focal_length_x[i] equal to 1 indicates that the sign is negative.

exponent_focal_length_x[i] specifies the exponent part of the focal length of the i-th camera in the horizontal direction. The value of exponent_focal_length_x[i] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified focal length.

mantissa_focal_length_x[i] specifies the mantissa part of the focal length of the i-th camera in the horizontal direction. The length of the mantissa_focal_length_x[i] syntax element in units of bits is variable and determined as follows:

– If exponent_focal_length_x[i] is equal to 0, the length is Max(0, prec_focal_length − 30).

– Otherwise (exponent_focal_length_x[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_focal_length_x[i] + prec_focal_length − 31).

sign_focal_length_y[i] equal to 0 indicates that the sign of the focal length of the i-th camera in the vertical direction is positive. sign_focal_length_y[i] equal to 1 indicates that the sign is negative.

exponent_focal_length_y[i] specifies the exponent part of the focal length of the i-th camera in the vertical direction. The value of exponent_focal_length_y[i] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified focal length.

mantissa_focal_length_y[i] specifies the mantissa part of the focal length of the i-th camera in the vertical direction.

The length of the mantissa_focal_length_y[i] syntax element in units of bits is variable and determined as follows:

– If exponent_focal_length_y[i] is equal to 0, the length is Max(0, prec_focal_length − 30).

– Otherwise (exponent_focal_length_y[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_focal_length_y[i] + prec_focal_length − 31).

sign_principal_point_x[i] equal to 0 indicates that the sign of the principal point of the i-th camera in the horizontal direction is positive. sign_principal_point_x[i] equal to 1 indicates that the sign is negative.

exponent_principal_point_x[i] specifies the exponent part of the principal point of the i-th camera in the horizontal direction. The value of exponent_principal_point_x[i] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified principal point.

mantissa_principal_point_x[i] specifies the mantissa part of the principal point of the i-th camera in the horizontal direction. The length of the mantissa_principal_point_x[i] syntax element in units of bits is variable and is determined as follows:

– If exponent_principal_point_x[i] is equal to 0, the length is Max(0, prec_principal_point − 30).

– Otherwise (exponent_principal_point_x[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_principal_point_x[i] + prec_principal_point − 31).

sign_principal_point_y[i] equal to 0 indicates that the sign of the principal point of the i-th camera in the vertical direction is positive. sign_principal_point_y[i] equal to 1 indicates that the sign is negative.

exponent_principal_point_y[i] specifies the exponent part of the principal point of the i-th camera in the vertical direction. The value of exponent_principal_point_y[i] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified principal point.

mantissa_principal_point_y[i] specifies the mantissa part of the principal point of the i-th camera in the vertical direction. The length of the mantissa_principal_point_y[i] syntax element in units of bits is variable and is determined as follows:

– If exponent_principal_point_y[i] is equal to 0, the length is Max(0, prec_principal_point − 30).

– Otherwise (exponent_principal_point_y[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_principal_point_y[i] + prec_principal_point − 31).

sign_skew_factor[i] equal to 0 indicates that the sign of the skew factor of the i-th camera is positive.

sign_skew_factor[i] equal to 1 indicates that the sign is negative.

exponent_skew_factor[i] specifies the exponent part of the skew factor of the i-th camera. The value of exponent_skew_factor[i] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified skew factor.

mantissa_skew_factor[i] specifies the mantissa part of the skew factor of the i-th camera. The length of the mantissa_skew_factor[i] syntax element in units of bits is variable and determined as follows:

– If exponent_skew_factor[i] is equal to 0, the length is Max(0, prec_skew_factor − 30).

– Otherwise (exponent_skew_factor[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_skew_factor[i] + prec_skew_factor − 31).

The intrinsic matrix A[i] for i-th camera is represented by

$$\begin{bmatrix} \mathrm{focalLengthX}[\,i\,] & \mathrm{skewFactor}[\,i\,] & \mathrm{principalPointX}[\,i\,] \\ 0 & \mathrm{focalLengthY}[\,i\,] & \mathrm{principalPointY}[\,i\,] \\ 0 & 0 & 1 \end{bmatrix} \tag{49}$$

prec_rotation_param specifies the exponent of the maximum allowable truncation error for rE[i][j][k] (see Equation 50) as given by $2^{-\mathrm{prec\_rotation\_param}}$. The value of prec_rotation_param shall be in the range of 0 to 31, inclusive.

prec_translation_param specifies the exponent of the maximum allowable truncation error for tE[i][j] (see Equation 51) as given by $2^{-\mathrm{prec\_translation\_param}}$. The value of prec_translation_param shall be in the range of 0 to 31, inclusive.

sign_r[i][j][k] equal to 0 indicates that the sign of (j, k) component of the rotation matrix for the i-th camera is positive. sign_r[i][j][k] equal to 1 indicates that the sign is negative.

exponent_r[i][j][k] specifies the exponent part of (j, k) component of the rotation matrix for the i-th camera. The value of exponent_r[i][j][k] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified rotation matrix.

mantissa_r[i][j][k] specifies the mantissa part of (j, k) component of the rotation matrix for the i-th camera. The length of the mantissa_r[i][j][k] syntax element in units of bits is variable and determined as follows:

– If exponent_r[i] is equal to 0, the length is Max(0, prec_rotation_param − 30).

– Otherwise (exponent_r[i] is in the range of 0 to 63, exclusive), the length is Max(0, exponent_r[i] + prec_rotation_param − 31).

The rotation matrix R[i] for i-th camera is represented as follows:

$$\begin{bmatrix} rE[\,i\,][\,0\,][\,0\,] & rE[\,i\,][\,0\,][1] & rE[\,i\,][\,0\,][\,2\,] \\ rE[\,i\,][1][\,0\,] & rE[\,i\,][1][1] & rE[\,i\,][1][\,2\,] \\ rE[\,i\,][\,2\,][\,0\,] & rE[\,i\,][\,2\,][1] & rE[\,i\,][\,2\,][\,2\,] \end{bmatrix} \tag{50}$$

sign_t[i][j] equal to 0 indicates that the sign of the j-th component of the translation vector for the i-th camera is positive. sign_t[i][j] equal to 1 indicates that the sign is negative.

exponent_t[i][j] specifies the exponent part of the j-th component of the translation vector for the i-th camera. The value of exponent_t[i][j] shall be in the range of 0 to 62, inclusive. The value 63 is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value 63 as indicating an unspecified translation vector.

mantissa_t[i][j] specifies the mantissa part of the j-th component of the translation vector for the i-th camera. The length v of the mantissa_t[i][j] syntax element in units of bits is variable and is determined as follows:

– If exponent_t[i] is equal to 0, the length v is set equal to Max(0, prec_translation_param − 30).

– Otherwise (0 < exponent_t[i] < 63), the length v is set equal to Max(0, exponent_t[i] + prec_translation_param − 31).

The translation vector T[i] for the i-th camera is represented by:

$$\begin{bmatrix} tE[\,i\,][\,0\,] \\ tE[\,i\,][1] \\ tE[\,i\,][\,2\,] \end{bmatrix} \tag{51}$$

The association between the camera parameter variables and corresponding syntax elements is specified by Table 16. Each component of the intrinsic and rotation matrices and the translation vector is obtained from the variables specified in Table 16 as the variable x computed as follows:

– If e is in the range of 0 to 63, exclusive, x is set equal to $(-1)^{s} * 2^{e-31} * (1 + n \div 2^{v})$.

– Otherwise (e is equal to 0), x is set equal to $(-1)^{s} * 2^{-(30 + v)} * n$.

NOTE – The above specification is similar to that found in IEC 60559:1989.

Table 16 – Association between camera parameter variables and syntax elements

x	**s**	**e**	**n**
focalLengthX[i]	sign_focal_length_x[i]	exponent_focal_length_x[i]	mantissa_focal_length_x[i]
focalLengthY[i]	sign_focal_length_y[i]	exponent_focal_length_y[i]	mantissa_focal_length_y[i]
principalPointX[i]	sign_principal_point_x[i]	exponent_principal_point_x[i]	mantissa_principal_point_x[i]
principalPointY[i]	sign_principal_point_y[i]	exponent_principal_point_y[i]	mantissa_principal_point_y[i]
skewFactor[i]	sign_skew_factor[i]	exponent_skew_factor[i]	mantissa_skew_factor[i]
rE[i][j][k]	sign_r[i][j][k]	exponent_r[i][j][k]	mantissa_r[i][j][k]
tE[i][j]	sign_t[i][j]	exponent_t[i][j]	mantissa_t[i][j]

8.21 Multiview view position SEI message

8.21.1 Multiview view position SEI message syntax

multiview_view_position(payloadSize) {	**Descriptor**
num_views_minus1	ue(v)
for(i = 0; i <= num_views_minus1; i++)	
view_position[i]	ue(v)
}	

8.21.2 Multiview view position SEI message semantics

The multiview view position SEI message specifies the relative view position along a single horizontal axis of views within a CVS.

When a multiview view position SEI message is present in any AU of a CVS, a multiview view position SEI message shall be present for the first AU of the CVS. All multiview view position SEI messages in a CVS shall have the same content.

When a CVS does not contain an SDI SEI message, the CVS shall not contain a multiview view position SEI message.

When an AU contains both an SDI SEI message and a multiview view position SEI message, the SDI SEI message shall precede the multiview view position SEI message in decoding order.

Some of the views for which the view position information is included in a multiview view position SEI message may not be present in the current CVS.

num_views_minus1 plus 1 shall be equal to NumViews derived from the SDI SEI message for the CVS.

view_position[i] indicates the order of the view with view identifier equal to ViewId[i] among all the views from left to right for the purpose of display, with the order for the left-most view being equal to 0 and the value of the order increasing by 1 for next view from left to right. The value of view_position[i] shall be in the range of 0 to 62, inclusive.

8.22 Depth representation information SEI message

8.22.1 Depth representation information SEI message syntax

depth_representation_info(payloadSize) {	**Descriptor**
z_near_flag	u(1)
z_far_flag	u(1)
d_min_flag	u(1)
d_max_flag	u(1)
depth_representation_type	ue(v)
if(d_min_flag || d_max_flag)	
disparity_ref_view_id	ue(v)
if(z_near_flag)	
depth_rep_info_element(ZNearSign, ZNearExp, ZNearMantissa, ZNearManLen)	
if(z_far_flag)	
depth_rep_info_element(ZFarSign, ZFarExp, ZFarMantissa, ZFarManLen)	
if(d_min_flag)	
depth_rep_info_element(DMinSign, DMinExp, DMinMantissa, DMinManLen)	
if(d_max_flag)	
depth_rep_info_element(DMaxSign, DMaxExp, DMaxMantissa, DMaxManLen)	
if(depth_representation_type = = 3) {	
depth_nonlinear_representation_num_minus1	ue(v)

for(i = 1; i <= depth_nonlinear_representation_num_minus1 + 1; i++)	
depth_nonlinear_representation_model[i]	ue(v)
}	
}	

8.22.1.1 Depth representation information element syntax

depth_rep_info_element(OutSign, OutExp, OutMantissa, OutManLen) {	**Descriptor**
da_sign_flag	u(1)
da_exponent	u(7)
da_mantissa_len_minus1	u(5)
da_mantissa	u(v)
}	

8.22.2 Depth representation information SEI message semantics

The syntax elements in the depth representation information (DRI) SEI message specify various parameters for auxiliary pictures of type AUX_DEPTH for the purpose of processing decoded primary and auxiliary pictures prior to rendering on a 3D display, such as view synthesis. Specifically, depth or disparity ranges for depth pictures are specified.

Use of this SEI message requires the definition of the following variable:

– A bit depth for the samples of the luma component, denoted herein by BitDepth_Y.

When a CVS does not contain an SDI SEI message with sdi_aux_id[i] equal to 2 for at least one value of i, no picture in the CVS shall be associated with a DRI SEI message.

When an AU contains both an SDI SEI message with sdi_aux_id[i] equal to 2 for at least one value of i and a DRI SEI message, the SDI SEI message shall precede the DRI SEI message in decoding order.

When present, the DRI SEI message shall be associated with one or more layers that are indicated as depth auxiliary layers by an SDI SEI message. The following semantics apply separately to each nuh_layer_id targetLayerId among the nuh_layer_id values to which the DRI SEI message applies.

When present, the DRI SEI message may be included in any access unit. It is recommended that, when present, the SEI message is included for the purpose of random access in an access unit in which the coded picture with nuh_layer_id equal to targetLayerId is an IRAP picture.

The information indicated in the SEI message applies to all the pictures with nuh_layer_id equal to targetLayerId from the access unit containing the SEI message up to but excluding the next picture, in decoding order, associated with a DRI SEI message applicable to targetLayerId or to the end of the CLVS of the nuh_layer_id equal to targetLayerId, whichever is earlier in decoding order.

z_near_flag equal to 0 specifies that the syntax elements specifying the nearest depth value are not present in the syntax structure. z_near_flag equal to 1 specifies that the syntax elements specifying the nearest depth value are present in the syntax structure.

z_far_flag equal to 0 specifies that the syntax elements specifying the farthest depth value are not present in the syntax structure. z_far_flag equal to 1 specifies that the syntax elements specifying the farthest depth value are present in the syntax structure.

d_min_flag equal to 0 specifies that the syntax elements specifying the minimum disparity value are not present in the syntax structure. d_min_flag equal to 1 specifies that the syntax elements specifying the minimum disparity value are present in the syntax structure.

d_max_flag equal to 0 specifies that the syntax elements specifying the maximum disparity value are not present in the syntax structure. d_max_flag equal to 1 specifies that the syntax elements specifying the maximum disparity value are present in the syntax structure.

depth_representation_type specifies the representation definition of decoded luma samples of auxiliary pictures as specified in Table 17. In Table 17, disparity specifies the horizontal displacement between two texture views and Z value specifies the distance from a camera. The value of depth_representation_type shall be in the range of 0 to 3, inclusive, in bitstreams conforming to this version of this document. The values of 4 to 15, inclusive, for depth_representation_type are reserved for future use by ITU-T | ISO/IEC. Although the value of depth_representation_type is required to be in the range of 0 to 3, inclusive, in this version of this document, decoders shall also allow values of depth_representation_type in the range of 4 to 15, inclusive, to appear in the syntax. Decoders conforming to this version of this document shall ignore the bits that follow a value of depth_representation_type in the range of 4 to 15, inclusive, in the depth representation information SEI message.

The variable maxVal is set equal to $(1 \ll \mathrm{BitDepth}_{Y}) - 1$.

Table 17 – Definition of depth_representation_type

depth_representation_type	Interpretation
0	Each decoded luma sample value of an auxiliary picture represents an inverse of Z value that is uniformly quantized into the range of 0 to maxVal, inclusive. When z_far_flag is equal to 1, the luma sample value equal to 0 represents the inverse of ZFar (specified below). When z_near_flag is equal to 1, the luma sample value equal to maxVal represents the inverse of ZNear (specified below).
1	Each decoded luma sample value of an auxiliary picture represents disparity that is uniformly quantized into the range of 0 to maxVal, inclusive. When d_min_flag is equal to 1, the luma sample value equal to 0 represents DMin (specified below). When d_max_flag is equal to 1, the luma sample value equal to maxVal represents DMax (specified below).
2	Each decoded luma sample value of an auxiliary picture represents a Z value uniformly quantized into the range of 0 to maxVal, inclusive. When z_far_flag is equal to 1, the luma sample value equal to 0 corresponds to ZFar (specified below). When z_near_flag is equal to 1, the luma sample value equal to maxVal represents ZNear (specified below).
3	Each decoded luma sample value of an auxiliary picture represents a nonlinearly mapped disparity, normalized in range from 0 to maxVal, as specified by depth_nonlinear_representation_num_minus1 and depth_nonlinear_representation_model[i]. When d_min_flag is equal to 1, the luma sample value equal to 0 represents DMin (specified below). When d_max_flag is equal to 1, the luma sample value equal to maxVal represents DMax (specified below).
Other values	Reserved for future use

disparity_ref_view_id specifies the view identifier for which the disparity values are derived. The value of disparity_ref_view_id shall be in the range of 0 to 1023, inclusive.

NOTE 1 – The view identifier of the i-th view in the current CVS is equal to ViewId[i] as specified in the semantics of the SDI SEI message in clause 8.19.2.

NOTE 2 – disparity_ref_view_id is present only if d_min_flag is equal to 1 or d_max_flag is equal to 1 and is useful for depth_representation_type values equal to 1 and 3.

The variables in the x column of Table 18 are derived from the respective variables in the s, e, n and v columns of Table 18 as follows:

– If the value of e is in the range of 0 to 127, exclusive, x is set equal to $(-1)^{s} * 2^{e-31} * (1 + n \div 2^{v})$.

– Otherwise (e is equal to 0), x is set equal to $(-1)^{s} * 2^{-(30 + v)} * n$.

NOTE 3 – The above specification is similar to that found in IEC 60559:1989.

Table 18 – Association between depth parameter variables and syntax elements

x	s	e	n	v
ZNear	ZNearSign	ZNearExp	ZNearMantissa	ZNearManLen
ZFar	ZFarSign	ZFarExp	ZFarMantissa	ZFarManLen
DMax	DMaxSign	DMaxExp	DMaxMantissa	DMaxManLen
DMin	DMinSign	DMinExp	DMinMantissa	DMinManLen

The DMin and DMax values, when present, are specified in units of a luma sample width of the associated primary picture of the auxiliary picture of type AUX_DEPTH.

The units for the ZNear and ZFar values, when present, are identical but unspecified.

depth_nonlinear_representation_num_minus1 plus 2 specifies the number of piece-wise linear segments for mapping of depth values to a scale that is uniformly quantized in terms of disparity. The value of depth_nonlinear_representation_num_minus1 shall be in the range of 0 to 62, inclusive.

depth_nonlinear_representation_model[i] for i ranging from 0 to depth_nonlinear_representation_num_minus1 + 2, inclusive, specify the piece-wise linear segments for mapping of decoded luma sample values of an auxiliary picture to a scale that is uniformly quantized in terms of disparity. The value of depth_nonlinear_representation_model[i] shall be in the range of 0 to 65 535, inclusive. The values of depth_nonlinear_representation_model[0] and depth_nonlinear_representation_model[depth_nonlinear_representation_num_minus1 + 2] are both inferred to be equal to 0.

NOTE 4 – When depth_representation_type is equal to 3, an auxiliary picture contains non-linearly transformed depth samples. The variable DepthLUT[i], as specified below, is used to transform decoded depth sample values from the non-linear representation to the linear representation, i.e., uniformly quantized disparity values. The shape of this transform is defined by means of line-segment approximation in two-dimensional linear-disparity-to-non-linear-disparity space. The first (0, 0) and the last (maxVal, maxVal) nodes of the curve are predefined. Positions of additional nodes are transmitted in form of deviations (depth_nonlinear_representation_model[i]) from the straight-line curve. These deviations are uniformly distributed along the whole range of 0 to maxVal, inclusive, with spacing depending on the value of depth_nonlinear_representation_num_minus1. The variable DepthLUT[i] for i in the range of 0 to maxVal, inclusive, is specified as follows:

```
for( k = 0; k  <=  depth_nonlinear_representation_num_minus1 + 1; k++ ) {
    pos1 = ( maxVal * k ) / (depth_nonlinear_representation_num_minus1 + 2 )
    dev1 = depth_nonlinear_representation_model[ k ]
    pos2 = ( maxVal * ( k + 1 ) ) / (depth_nonlinear_representation_num_minus1 + 2 )
    dev2 = depth_nonlinear_representation_model[ k + 1 ]                          (52)

    x1 = pos1 − dev1
    y1 = pos1 + dev1
    x2 = pos2 − dev2
    y2 = pos2 + dev2

    for( x = Max( x1, 0 ); x  <=  Min( x2, maxVal ); x++ )
        DepthLUT[ x ] = Clip3( 0, maxVal, Round( ( ( x − x1 ) * ( y2 − y1 ) ) ÷ ( x2 − x1 ) + y1 ) )
}
```

When depth_representation_type is equal to 3, DepthLUT[dS] for all decoded luma sample values dS of an auxiliary picture in the range of 0 to maxVal, inclusive, represents disparity that is uniformly quantized into the range of 0 to maxVal, inclusive.

8.22.2.1 Depth representation information element semantics

The syntax structure specifies the value of an element in the DRI SEI message.

The depth_rep_info_element(OutSign, OutExp, OutMantissa, OutManLen) syntax structure sets the values of the OutSign, OutExp, OutMantissa and OutManLen variables that represent a floating-point value. When the syntax structure is included in another syntax structure, the variable names OutSign, OutExp, OutMantissa and OutManLen are to be interpreted as being replaced by the variable names used when the syntax structure is included.

da_sign_flag equal to 0 indicates that the sign of the floating-point value is positive. da_sign_flag equal to 1 indicates that the sign is negative. The variable OutSign is set equal to da_sign_flag.

da_exponent specifies the exponent of the floating-point value. The value of da_exponent shall be in the range of 0 to $2^7 - 2$, inclusive. The value $2^7 - 1$ is reserved for future use by ITU-T | ISO/IEC. Decoders shall treat the value $2^7 - 1$ as indicating an unspecified value. The variable OutExp is set equal to da_exponent.

da_mantissa_len_minus1 plus 1 specifies the number of bits in the da_mantissa syntax element. The variable OutManLen is set equal to da_mantissa_len_minus1 + 1.

da_mantissa specifies the mantissa of the floating-point value. The variable OutMantissa is set equal to da_mantissa.

8.23 Alpha channel information SEI message

8.23.1 Alpha channel information SEI message syntax

alpha_channel_info(payloadSize) {	**Descriptor**
alpha_channel_cancel_flag	u(1)
if(!alpha_channel_cancel_flag) {	

alpha_channel_use_idc	u(3)
alpha_channel_bit_depth_minus8	u(3)
alpha_transparent_value	u(v)
alpha_opaque_value	u(v)
alpha_channel_incr_flag	u(1)
alpha_channel_clip_flag	u(1)
if(alpha_channel_clip_flag)	
alpha_channel_clip_type_flag	u(1)
}	
}	

8.23.2 Alpha channel information SEI message semantics

The alpha channel information (ACI) SEI message provides information about alpha channel sample values and post-processing applied to the decoded alpha planes coded in auxiliary pictures of type AUX_ALPHA and one or more associated primary pictures.

When a CVS does not contain an SDI SEI message with sdi_aux_id[i] equal to 1 for at least one value of i, no picture in the CVS shall be associated with an ACI SEI message.

When an AU contains both an SDI SEI message with sdi_aux_id[i] equal to 1 for at least one value of i and an ACI SEI message, the SDI SEI message shall precede the ACI SEI message in decoding order.

When an access unit contains an auxiliary picture picA in a layer, with nuh_layer_id equal to nuhLayerIdA, that is indicated as an alpha auxiliary layer by an SDI SEI message, the alpha channel sample values of picA persist in output order until one or more of the following conditions are true:

– The next picture, in output order, with nuh_layer_id equal to nuhLayerIdA is output.
– A CLVS containing the auxiliary picture picA ends.
– The bitstream ends.
– A CLVS of any associated primary layer of the auxiliary picture layer with nuh_layer_id equal to nuhLayerIdA ends.

The following semantics apply separately to each nuh_layer_id targetLayerId among the nuh_layer_id values to which the ACI SEI message applies.

alpha_channel_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous ACI SEI message in output order that applies to the current layer. alpha_channel_cancel_flag equal to 0 indicates that ACI follows.

Let currPic be the picture that the ACI SEI message is associated with. The semantics of ACI SEI message persist for the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.
– The bitstream ends.
– A picture in the current layer in an AU associated with an ACI SEI message is output that follows the current picture in output order.

alpha_channel_use_idc equal to 0 indicates that for alpha blending purposes the decoded samples of the associated primary picture should be multiplied by the interpretation sample values of the decoded auxiliary picture in the display process after output from the decoding process. alpha_channel_use_idc equal to 1 indicates that for alpha blending purposes the decoded samples of the associated primary picture should not be multiplied by the interpretation sample values of the decoded auxiliary picture in the display process after output from the decoding process. alpha_channel_use_idc equal to 2 indicates that the usage of the auxiliary picture is unspecified. Values greater than 2 for alpha_channel_use_idc are reserved for future use by ITU-T | ISO/IEC. When not present, the value of alpha_channel_use_idc is inferred to be equal to 2. Decoders shall ignore alpha channel information SEI messages in which alpha_channel_use_idc is greater than 2.

alpha_channel_bit_depth_minus8 plus 8 specifies the bit depth of the samples of the luma sample array of the auxiliary picture. alpha_channel_bit_depth_minus8 plus 8 shall be equal to the bit depth of the associated primary picture.

alpha_transparent_value specifies the interpretation sample value of a decoded auxiliary picture luma sample for which the associated luma and chroma samples of the primary coded picture are considered transparent for purposes of alpha blending. The number of bits used for the representation of the alpha_transparent_value syntax element is alpha_channel_bit_depth_minus8 + 9.

alpha_opaque_value specifies the interpretation sample value of a decoded auxiliary picture luma sample for which the associated luma and chroma samples of the primary coded picture are considered opaque for purposes of alpha blending. The number of bits used for the representation of the alpha_opaque_value syntax element is alpha_channel_bit_depth_minus8 + 9.

A value of alpha_opaque_value that is equal to alpha_transparent_value indicates that the auxiliary coded picture is not intended for alpha blending purposes.

NOTE 1 – For alpha blending purposes, alpha_opaque_value can be greater than alpha_transparent_value or it can be less than or equal to alpha_transparent_value.

alpha_channel_incr_flag equal to 0 indicates that the interpretation sample value for each decoded auxiliary picture luma sample value is equal to the decoded auxiliary picture sample value for purposes of alpha blending. alpha_channel_incr_flag equal to 1 indicates that, for purposes of alpha blending, after decoding the auxiliary picture samples, any auxiliary picture luma sample value that is greater than Min(alpha_opaque_value, alpha_transparent_value) should be increased by one to obtain the interpretation sample value for the auxiliary picture sample and any auxiliary picture luma sample value that is less than or equal to Min(alpha_opaque_value, alpha_transparent_value) should be used, without alteration, as the interpretation sample value for the decoded auxiliary picture sample value.

When alpha_transparent_value is equal to alpha_opaque_value or Log2(Abs(alpha_opaque_value − alpha_transparent_value)) does not have an integer value, alpha_channel_incr_flag shall be equal to 0.

alpha_channel_clip_flag equal to 0 indicates that no clipping operation is applied to obtain the interpretation sample values of the decoded auxiliary picture. alpha_channel_clip_flag equal to 1 indicates that the interpretation sample values of the decoded auxiliary picture are altered according to the clipping process described by the alpha_channel_clip_type_flag syntax element.

alpha_channel_clip_type_flag equal to 0 indicates that, for purposes of alpha blending, after decoding the auxiliary picture samples, any auxiliary picture luma sample that is greater than (alpha_opaque_value + alpha_transparent_value) / 2 is set equal to Max(alpha_transparent_value, alpha_opaque_value) to obtain the interpretation sample value for the auxiliary picture luma sample and any auxiliary picture luma sample that is less or equal than (alpha_opaque_value + alpha_transparent_value) / 2 is set equal to Min(alpha_transparent_value, alpha_opaque_value) to obtain the interpretation sample value for the auxiliary picture luma sample. alpha_channel_clip_type_flag equal to 1 indicates that, for purposes of alpha blending, after decoding the auxiliary picture samples, any auxiliary picture luma sample that is greater than Max(alpha_transparent_value, alpha_opaque_value) is set equal to Max(alpha_transparent_value, alpha_opaque_value) to obtain the interpretation sample value for the auxiliary picture luma sample and any auxiliary picture luma sample that is less than or equal to Min(alpha_transparent_value, alpha_opaque_value) is set equal to Min(alpha_transparent_value, alpha_opaque_value) to obtain the interpretation sample value for the auxiliary picture luma sample.

When both alpha_channel_incr_flag and alpha_channel_clip_flag are equal to one, the clipping operation specified by alpha_channel_clip_type_flag should be applied first, followed by the alteration specified by alpha_channel_incr_flag, to obtain the interpretation sample value for the auxiliary picture luma sample.

Alpha blending composition is ordinarily performed with a background picture B, a foreground picture F, and a decoded auxiliary picture A, all of the same size. Assume for purposes of example illustration that the chroma resolutions of B and F, if different from the luma resolution, have been upsampled to the same resolution as the luma. Denote corresponding samples of B, F and A by b, f and a, respectively. Denote luma and chroma samples by subscripts Y, Cb and Cr. Each component, e.g., Y, is also assumed for purposes of example illustration to have the same bit depth in each of the pictures B and F. However, different components, e.g., Y and Cb, can have different bit depths in this example. The samples of pictures B and F may alternatively represent green, blue and red component values (see clause 7.3), although the equations use the subscripts Y, Cb and Cr for the three components.

Define the variables alphaRange, alphaFwt and alphaBwt for each luma sample a_Y of the auxiliary picture A as follows:

$$\text{alphaRange} = \text{Abs}(\ \text{alpha\_opaque\_value} - \text{alpha\_transparent\_value}\ ) \tag{53}$$

$$\text{alphaFwt} = \text{Abs}(\ a_Y - \text{alpha\_transparent\_value}\ ) \tag{54}$$

$$\text{alphaBwt} = \text{Abs}(\ a_Y - \text{alpha\_opaque\_value}\ ) \tag{55}$$

A picture format that is often useful for editing or direct viewing, and that is commonly used, is called pre-multiplied-black video. Pre-multiplied-black video has the characteristic that the decoded picture F will appear the same regardless of whether it is viewed directly without alpha blending composition or is alpha blended with a black background. The use of alpha_channel_use_idc equal to 0 corresponds with source video that is not pre-multiplied-black video, and the use of alpha_channel_use_idc equal to 1 corresponds with source video that is pre-multiplied-black video.

An example of operation of the alpha blending composition process to produce a displayed picture D with sample values d from the pictures B and F is as follows:

– If alpha_channel_use_idc is equal to 0, the samples d of the displayed picture D are calculated as follows:

$$d_Y = (\text{alphaFwt} * f_Y + \text{alphaBwt} * b_Y + \text{alphaRange} / 2) / \text{alphaRange} \quad (56)$$

$$d_{Cb} = (\text{alphaFwt} * f_{Cb} + \text{alphaBwt} * b_{Cb} + \text{alphaRange} / 2) / \text{alphaRange} \quad (57)$$

$$d_{Cr} = (\text{alphaFwt} * f_{Cr} + \text{alphaBwt} * b_{Cr} + \text{alphaRange} / 2) / \text{alphaRange} \quad (58)$$

– Otherwise (alpha_channel_use_idc is equal to 1), the samples d of the displayed picture D are calculated as follows:

$$d_Y = f_Y + (\text{alphaBwt} * b_Y + \text{alphaRange} / 2) / \text{alphaRange} \quad (59)$$

$$d_{Cb} = f_{Cb} + (\text{alphaBwt} * b_{Cb} + \text{alphaRange} / 2) / \text{alphaRange} \quad (60)$$

$$d_{Cr} = f_{Cr} + (\text{alphaBwt} * b_{Cr} + \text{alphaRange} / 2) / \text{alphaRange} \quad (61)$$

NOTE 2 – In this case, it is expected that the encoder produces its pre-multipled-black source video picture S with sample values s from some original input picture T with sample values t as expressed by Equations 62 to 64, so that when the decoded picture F is a close approximation of the pre-multipled-black source video picture S, the cascaded effect of Equations 62 to 64 followed by Equations 59 to 61 is approximately the same as expressed in Equations 56 to 58.

$$s_Y = (\text{alphaFwt} * t_Y) / \text{alphaRange} \quad (62)$$

$$s_{Cb} = (\text{alphaFwt} * t_{Cb}) / \text{alphaRange} \quad (63)$$

$$s_{Cr} = (\text{alphaFwt} * t_{Cr}) / \text{alphaRange} \quad (64)$$

NOTE 3 – In the event that the background picture B is represented using green, blue and red component values (see clause 7.3) in a manner such that the colour black is represented by all three component values being equal to 0, when the background picture B is black, the operation expressed by Equations 59 to 61 becomes simply $d_Y = f_Y$, $d_{Cb} = f_{Cb}$, and $d_{Cr} = f_{Cr}$. This can help to explain the "pre-multiplied black" term, as the expressions in Equations 62 to 64 are referred to as the pre-multiplication for the black background combination.

For the case with alpha_channel_use_idc equal to 1, somewhat modified processing should be applied when the colour representation domain is different from the use of green, blue, and red colour component values, or with the use of a non-zero black level. Unless the colour black is represented by all three component values b_Y, b_{Cb}, and b_{Cr} being equal to 0, Equations 59 to 61 do not simplify to $d_Y = f_Y$, $d_{Cb} = f_{Cb}$, and $d_{Cr} = f_{Cr}$ for pre-multiplied-black video content.

8.24 Extended DRAP indication SEI message

8.24.1 Extended DRAP indication SEI message syntax

extended_drap_indication(payloadSize) {	**Descriptor**
edrap_rap_id_minus1	u(16)
edrap_leading_pictures_decodable_flag	u(1)
edrap_reserved_zero_12bits	u(12)
edrap_num_ref_rap_pics_minus1	u(3)
for(i = 0; i <= edrap_num_ref_rap_pics_minus1; i++)	
edrap_ref_rap_id[i]	u(16)
}	

8.24.2 Extended DRAP indication SEI message semantics

The picture associated with an extended DRAP (EDRAP) indication SEI message is referred to as an EDRAP picture.

The presence of the EDRAP indication SEI message indicates that the constraints on picture order and picture referencing specified in this clause apply. These constraints can enable a decoder to properly decode the EDRAP picture and the pictures that are in the same layer and follow it in both decoding order and output order without needing to decode any other pictures in the same layer except the list of pictures referenceablePictures, which consists of a list of IRAP or EDRAP pictures in decoding order that are within the same CLVS and identified by the edrap_ref_rap_id[i] syntax elements.

The constraints indicated by the presence of the EDRAP indication SEI message, which shall all apply, are as follows:

– The EDRAP picture is a trailing picture.
– The EDRAP picture has a temporal sublayer identifier equal to 0.
– The EDRAP picture does not include any pictures in the same layer in the active entries of its reference picture lists except the referenceablePictures.
– Any picture that is in the same layer and follows the EDRAP picture in both decoding order and output order does not include, in the active entries of its reference picture lists, any picture that is in the same layer and precedes the EDRAP picture in decoding order or output order, with the exception of the referenceablePictures.
– Any picture in the list referenceablePictures does not include, in the active entries of its reference picture lists, any picture that is in the same layer and is not a picture at an earlier position in the list referenceablePictures.

NOTE – Consequently, the first picture in referenceablePictures, even when it is an EDRAP picture instead of an IRAP picture, does not include any picture from the same layer in the active entries of its reference picture lists.

edrap_rap_id_minus1 plus 1 specifies the RAP picture identifier, denoted as RapPicId, of the EDRAP picture.

Each IRAP or EDRAP picture is associated with a RapPicId value. The RapPicId value for an IRAP picture is inferred to be equal to 0. The RapPicId values for any two EDRAP pictures associated with the same IRAP picture shall be different.

edrap_leading_pictures_decodable_flag equal to 1 specifies that both of the following constraints apply:

– Any picture that is in the same layer and follows the EDRAP picture in decoding order shall follow, in output order, any picture that is in the same layer and precedes the EDRAP picture in decoding order.
– Any picture that is in the same layer and follows the EDRAP picture in decoding order and precedes the EDRAP picture in output order shall not include, in the active entries of its reference picture lists, any picture that is in the same layer and precedes the EDRAP picture in decoding order, with the exception of the referenceablePictures.

edrap_leading_pictures_decodable_flag equal to 0 does not impose such constraints.

edrap_reserved_zero_12bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for edrap_reserved_zero_12bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of edrap_reserved_zero_12bits.

edrap_num_ref_rap_pics_minus1 plus 1 indicates the number of IRAP or EDRAP pictures that are within the same CLVS as the EDRAP picture and may be included in the active entries of the reference picture lists of the EDRAP picture.

edrap_ref_rap_id[i] indicates RapPicId of the i-th RAP picture that may be included in the active entries of the reference picture lists of the EDRAP picture. The i-th RAP picture shall be either the IRAP picture associated with the current EDRAP picture or an EDRAP picture associated with the same IRAP picture as the current EDRAP picture.

8.25 Display orientation SEI message

8.25.1 Display orientation SEI message syntax

display_orientation(payloadSize) {	**Descriptor**
display_orientation_cancel_flag	u(1)
if(!display_orientation_cancel_flag) {	
display_orientation_persistence_flag	u(1)
display_orientation_transform_type	u(3)
display_orientation_reserved_zero_3bits	u(3)
}	

8.25.2 Display orientation SEI message semantics

When the associated picture has PicOutputFlag equal to 1, the display orientation SEI message informs the decoder of a transformation that is recommended to be applied to the cropped decoded picture prior to display.

display_orientation_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous display orientation SEI message in output order. display_orientation_cancel_flag equal to 0 indicates that display orientation information follows.

display_orientation_persistence_flag specifies the persistence of the display orientation SEI message for the current layer.

display_orientation_persistence_flag equal to 0 specifies that the display orientation SEI message applies to the current decoded picture only.

display_orientation_persistence_flag equal to 1 specifies that the display orientation SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a display orientation SEI message is output that follows the current picture in output order.

display_orientation_transform_type specifies the rotation and mirroring to be applied to the picture. When display_orientation_transform_type specifies both rotation and mirroring, rotation applies before mirroring. The values of display_transform_type are specified in Table 19.

Table 19 – display_orientation_transform_type values

Value	Description
0	no transform
1	mirroring horizontally
2	rotation by 180 degrees (anticlockwise)
3	rotation by 180 degrees (anticlockwise) before mirroring horizontally
4	rotation by 90 degrees (anticlockwise) before mirroring horizontally
5	rotation by 90 degrees (anticlockwise)
6	rotation by 270 degrees (anticlockwise) before mirroring horizontally
7	rotation by 270 degrees (anticlockwise)

display_orientation_reserved_zero_3bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for display_orientation_reserved_zero_3bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of display_orientation_reserved_zero_3bits.

8.26 Colour transform information SEI message

8.26.1 Colour transform information SEI message syntax

colour_transform_info(payloadSize) {	**Descriptor**
colour_transform_id	ue(v)
colour_transform_cancel_flag	u(1)
if(!colour_transform_cancel_flag) {	
colour_transform_persistence_flag	u(1)
colour_transform_video_signal_info_present_flag	u(1)
if(colour_transform_video_signal_info_present_flag) {	
colour_transform_full_range_flag	u(1)
colour_tranform_primaries	u(8)
colour_transform_transfer_function	u(8)
colour_transform_matrix_coefficients	u(8)
}	
colour_transform_bit_depth_minus8	u(4)
colour_transform_log2_number_of_points_per_lut_minus1	u(3)
colour_transform_cross_component_flag	u(1)

if(colour_transform _cross_component_flag)	
colour_transform_cross_comp_inferred_flag	u(1)
for(i = 0; i < colourTransformSize; i++)	
colour_transf_lut[0][i]	u(v)
if(colour_transform_cross_component_flag = = 0 || colour_transform_cross_comp_inferred_flag = = 0) {	
colour_transform_lut2_present_flag	u(1)
for(i = 0; i < colourTransformSize; i++)	
colour_transf_lut[1][i]	u(v)
if(colour_transform_lut2_present_flag)	
for(i = 0; i < colourTransformSize; i++)	
colour_transf_lut[2][i]	u(v)
} else	
colour_transform_chroma_offset	u(v)
}	
}	

8.26.2 Colour transform information SEI message semantics

The colour transform information (CTI) SEI message provides information to enable remapping of the reconstructed colour samples of the output pictures for purposes such as converting the output pictures to a representation that is more suitable for an alternative display. The colour transform model used in the CTI SEI message is composed of a first piece-wise linear function applied to the first colour component. Depending on the values of syntax elements colour_transform_cross_component_flag, colour_transform_cross_comp_inferred_flag, and colour_transform_lut2_present_flag, one or two additional piece-wise linear functions may be signalled for the second and third colour components.

When ChromaFormatIdc is equal to 0 (monochrome), the CTI SEI message shall not be present, although decoders shall also allow such messages to be present and shall ignore any such CTI SEI messages when present.

colour_transform_id contains an identifying number that may be used to identify the purpose of the CTI. The value of colour_transform_id may be used (in a manner not specified in this Specification) to indicate that the input to the remapping process is the output of some conversion process that is not specified in this Specification, such as a conversion of the picture to some alternative colour representation (e.g., conversion from a YCbCr colour representation to a GBR colour representation). When more than one CTI SEI message is present with the same value of colour_transform_id, the content of these CTI SEI messages shall be the same. When CTI SEI messages are present that have more than one value of colour_transform_id, this may indicate that the remapping processes indicated by the different values of colour_transform_id are alternatives that are provided for different purposes or that a cascading of remapping processes is to be applied in a sequential order (an order that is not specified in this Specification). The value of colour_transform_id shall be in the range of 0 to $2^{32} - 2$, inclusive.

Values of colour_transform_id from 0 to 255 and from 512 to $2^{31} - 1$ may be used as determined by the application. Values of colour_transform_id from 256 to 511, inclusive, and from 2^{31} to $2^{32} - 2$, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the CTI SEI messages containing a value of colour_transform_id in the range of 256 to 511, inclusive, or in the range of 2^{31} to $2^{32} - 2$, inclusive, and bitstreams conforming to this version of this Specification shall not contain colour_transform_id with such values.

NOTE – The colour_transform_id can be used to support different remapping processes that are suitable for different display scenarios. For example, different values of colour_transform_id may correspond to different remapped colour spaces supported by displays.

colour_transform_cancel_flag equal to 1 indicates that the CTI SEI message cancels the persistence of any previous CTI SEI message in output order that applies to the current layer. colour_transform_cancel_flag equal to 0 indicates that CTI follows.

colour_transform_persistence_flag specifies the persistence of the CTI SEI message for the current layer.

colour_transform_persistence_flag equal to 0 specifies that the CTI SEI message applies to the current decoded picture only.

colour_transform_persistence_flag equal to 1 specifies that the CTI SEI message applies to the current decoded picture and persists for all subsequent pictures of the current layer in output order until one or more of the following conditions are true:

– A new CLVS of the current layer begins.

– The bitstream ends.

– A picture in the current layer in an AU associated with a CTI SEI message is output that follows the current picture in output order.

colour_transform_video_signal_info_present_flag equal to 1 specifies that syntax elements colour_transform_full_range_flag, colour_transform_primaries, colour_transform_transfer_function and colour_transform_matrix_coefficients are present, colour_transform_video_signal_info_present_flag equal to 0 specifies that syntax elements colour_transform_full_range_flag, colour_transform_primaries, colour_transform_transfer_function and colour_transform_matrix_coefficients are not present.

colour_transform_full_range_flag has the same semantics as specified in clause 7.3 for the vui_full_range_flag syntax element, except that colour_transform_full_range_flag identifies the colour space of the remapped reconstructed picture, rather than the colour space used for the CLVS. When not present, the value of colour_transform_full_range_flag is inferred to be equal to the value of vui_full_range_flag.

colour_transform_primaries has the same semantics as specified in clause 7.3 for the vui_colour_primaries syntax element, except that colour_transform_primaries identifies the colour space of the remapped reconstructed picture, rather than the colour space used for the CLVS. When not present, the value of colour_transform_primaries is inferred to be equal to the value of vui_colour_primaries.

colour_transform_transfer_function has the same semantics as specified in clause 7.3 for the vui_transfer_characteristics syntax element, except that colour_transform_transfer_function identifies the colour space of the remapped reconstructed picture, rather than the colour space used for the CLVS. When not present, the value of colour_transform_transfer_function is inferred to be equal to the value of vui_transfer_characteristics.

colour_transform_matrix_coefficients has the same semantics as specified in clause 7.3 for the vui_matrix_coeffs syntax element, except that colour_transform_matrix_coefficients identifies the colour space of the remapped reconstructed picture, rather than the colour space used for the CLVS. When not present, the value of colour_transform_matrix_coefficients is inferred to be equal to the value of vui_matrix_coeffs.

colour_transform_bit_depth_minus8 plus 8 specifies the bit depth of the colour components of the associated pictures for purposes of interpretation of the CTI SEI message. When any CTI SEI message is present with the value of colour_transform_bit_depth plus 8 not equal to the bit depth of the decoded colour components, the SEI message refers to the hypothetical result of a conversion operation performed to convert the decoded colour component samples to the bit depth equal to colour_transform_input_bit_depth plus 8.

The value of colour_transform_bit_depth plus 8 shall be in the range of 8 to 16, inclusive. Values of colour_transform_bit_depth from in the range of 17 to 23, inclusive, are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the CTI SEI messages that contain a value of colour_transform_bit_depth in the range of 17 to 23, inclusive, and bitstreams conforming to this version of this Specification shall not contain colour_transform_bit_depth with such values.

bitDepth is set equal to (colour_transform_bit_depth + 8).

colour_transform_log2_number_of_points_per_lut_minus1 specifies the log2 of the number of pivot points in the piece-wise linear remapping functions minus 1.

log2numLutPoints is set equal to (colour_transform_log2_number_of_points_per_lut_minus1 + 1).

numLutPoints is set equal to (1 << log2numLutPoints).

colourTransformSize is set equal to (numLutPoints + 1).

log2distX is set equal to (bitDepth − log2numLutPoints).

colour_transform_cross_component_flag equal to 1 indicates that the remapping of the second and third colour components is performed as cross-component remapping based on the first colour component. colour_transform_cross_component_flag equal to 0 indicates that intra-component remapping is applied to the second and third colour components.

maxIntraComp is set equal to (2 * (1 − colour_transform_cross_component_flag)).

colour_transform_cross_comp_inferred_flag equal to 1 indicates that the remapping piece-wise linear functions of the second and third colour components are inferred from the remapping piece-wise linear function of the first colour component. colour_transform_cross_comp_inferred_flag equal to 0 indicates that the remapping piece-wise linear functions of the second and third colour components are signalled. When not present, the value of colour_transform_cross_comp_inferred_flag is inferred to be equal to 0.

colour_transf_lut[c][i] specifies the piecewise linear remapping function of the colour component of index c. When colour_transf_lut[1][i] is present and colour_transf_lut[2][i] is not present, the value of colour_transf_lut[2][i] is inferred to be equal to colour_transf_lut[1][i]. The length of colour_transf_lut[c][i] is 2 + bitDepth – log2numLutPoints bits.

colour_transform_lut2_present_flag equal to 1 specifies that colour_transf_lut[2][i] is present in the CTI SEI message. colour_transform_lut2_present_flag equal to 0 specifies that colour_transf_lut[2][i] is not present in the CTI SEI message. When not present, the value of colour_transform_lut2_present_flag is inferred to be equal to 0.

colour_transform_chroma_offset specifies the CTI chroma offset. When not present, colour_transform_chroma_offset is inferred to be equal to 0. The length of colour_transform_chroma_offset is 2 + bitDepth – log2numLutPoints bits.

The remapping process of the input picture components rec[c], with width and height equal to picWidth[c] and picHeight[c], respectively, to the output remapped picture components map[c], for c=0..2, is performed as follows.

The array pivotPointX is derived as follows.

– For j=0 ..(numLutPoints − 1), pivotPointX[j] is set equal to (j << log2distX).

For c=0..maxIntraComp, the arrays pivotPointY[c] and slope[c] are derived as follows:

– pivotPointY[c][0] is set equal to colour_transf_lut[c][0]

– For j=1..(numLutPoints − 1), pivotPointY[c][j] is derived as follows:

pivotPointY[c][j] = pivotPointY[c][j − 1] + colour_transf_lut[c][j] (65)

– For j=0..(numLutPoints − 1), slope[c][j] is derived as follows:

slope[c][j] = ((colour_transf_lut[c][j + 1] << 11) + (1 << (log2distX − 1))) >> log2distX (66)

When colour_transform_cross_component_flag is equal to 1, the arrays ccPivotPointY[c] and ccSlope[c] are derived as follows, for c=1..2:

– If colour_transform_cross_comp_inferred_flag is equal to 0, ccPivotPointY[c] is derived as follows:
  – For j=0..numLutPoints, ccPivotPointY[c][j] is set equal to (colour_transf_lut[c][j] << (11 − log2distX)).
– Otherwise (colour_transform_cross_comp_inferred_flag is equal to 1), ccPivotPointY[c] is derived as follows:
  – For j=0..(numLutPoints − 1), tmpPivotPt[j] is derived as follows:
    – If colour_transf_lut[0][j + 1] is equal to 0, tmpPivotPt[j] is set equal to (1 << 11).
    – Otherwise, tmpPivotPt[j] is derived as follows:

      tmpPivotPt[j] = (colour_transf_lut[0][j + 1] + colour_transform_chroma_offset) << (11 – log2distX) (67)

  – The array ccPivotPointY[c] is derived as follows:
    – For j=1..(numLutPoints − 1), ccPivotPointY[c][j] is derived as follows:

      ccPivotPointY[c][j] = (tmpPivotPt[j] + tmpPivotPt[j − 1] + 1) / 2 (68)

    – ccPivotPointY[c][0] is set equal to tmpPivotPt[0].
    – ccPivotPointY[c][numLutPoints] is set equal to tmpPivotPt[numLutPoints − 1].
– For j=0..(numLutPoints − 1), the value of ccSlope[c][j] is set equal to (ccPivotPointY[c][j + 1] − ccPivotPointY[c][j]).

For c=0..maxIntraComp, the intra-component remapping process of the input samples picture rec[c] into the remapped samples picture map[c] is performed as follows.

– for i=0..picWidth[c] − 1, j=0..picHeight[c] − 1, the following applies:

idx = rec[c][i][j] >> log2distX
map[c][i][j] = Clip3(0, (1 << bitDepth) − 1, pivotPointY[c][idx] + ((slope[c][idx] * (rec[i][j] − pivotPointX[idx]) + (1 << 10)) >> 11)) (69)

When colour_transform_cross_component_flag is equal to 1, for c=1..2, the cross-component remapping process of the input samples picture rec[c] into the remapped samples picture map[c] is performed as follows:

– offset is set equal to $(1 \ll (\text{bitDepth} - 1))$.

– subWc and subHc are set equal to (picWidth[0] / picWidth[c]) and (picHeight[0] / picHeight[c]), respectively.

– For i=0..picWidth[c] − 1, j=0..picHeight[c] − 1, the following applies:

$$\begin{aligned}
&\text{coloc} = \text{rec}[\,0\,][\,i * \text{SubWc}\,][\,j * \text{SubHc}\,]\\
&\text{idx} = \text{coloc} \gg \text{log2distX}\\
&\text{scale} = \text{ccPivotPointY}[\,c\,][\,\text{idx}\,] + ((\text{ccSlope}[\,c\,][\,\text{idx}\,] * (\text{coloc} - \text{pivotPointX}[\,\text{idx}\,])) \gg \text{log2distX})\\
&\text{map}[\,c\,][\,i\,][\,j\,] = \text{Clip3}(0, (1 \ll \text{bitDepth}) - 1,\\
&\qquad ((\text{offset} \ll 11) + \text{scale} * (\text{rec}[\,c\,][\,i\,][\,j\,] - \text{offset}) + (1 \ll 10)) \gg 11)
\end{aligned} \tag{70}$$

8.27 Reserved SEI message

8.27.1 Reserved SEI message syntax

reserved_message(payloadSize) {	**Descriptor**
for(i = 0; i < payloadSize; i++)	
reserved_message_payload_byte	u(8)
}	

8.27.2 Reserved SEI message semantics

The reserved SEI message consists of data reserved for future backward-compatible use by ITU-T | ISO/IEC. Unless otherwise specified by a referencing specification, coded video bitstreams shall not contain reserved SEI messages and systems that make use of such coded video bitstreams shall not otherwise send reserved SEI messages until and unless the use of such messages has been specified by ITU-T | ISO/IEC. Decoders shall ignore reserved SEI messages.

reserved_message_payload_byte, when present, has values to be specified in the future by ITU-T | ISO/IEC.

9 Parsing process for k-th order Exp-Golomb codes

9.1 General

This process is invoked when the descriptor of a syntax element in the syntax tables is equal to ue(v) or se(v).

Inputs to this process are bits from the bitstream.

Outputs of this process are syntax element values.

Syntax elements coded as ue(v) or se(v) are Exp-Golomb-coded with order k equal to 0. The parsing process for these syntax elements begins with reading the bits starting at the current location in the bitstream up to and including the first non-zero bit, and counting the number of leading bits that are equal to 0. This process is specified as follows:

```
leadingZeroBits = −1
for( b = 0; !b; leadingZeroBits++ )                                    (71)
    b = read_bits( 1 )
```

The variable codeNum is then assigned as follows:

$$\text{codeNum} = (2^{\text{leadingZeroBits}} - 1) * 2^{k} + \text{read\_bits}(\text{leadingZeroBits} + k) \tag{72}$$

where the value returned from read_bits(leadingZeroBits) is interpreted as a binary representation of an unsigned integer with most significant bit written first.

Table 20 illustrates the structure of the 0-th order Exp-Golomb code by separating the bit string into "prefix" and "suffix" bits. The "prefix" bits are those bits that are parsed as specified for the computation of leadingZeroBits, and are shown as either 0 or 1 in the bit string column of Table 20. The "suffix" bits are those bits that are parsed in the computation of codeNum and are shown as x_i in Table 20, with i in the range of 0 to leadingZeroBits − 1, inclusive. Each x_i is equal to either 0 or 1.

Table 20 – Bit strings with "prefix" and "suffix" bits and assignment to codeNum ranges (informative)

Bit string form	Range of codeNum
1	0
0 1 x_0	1..2
0 0 1 x_1 x_0	3..6
0 0 0 1 x_2 x_1 x_0	7..14
0 0 0 0 1 x_3 x_2 x_1 x_0	15..30
0 0 0 0 0 1 x_4 x_3 x_2 x_1 x_0	31..62
...	...

Table 21 illustrates explicitly the assignment of bit strings to codeNum values.

Table 21 – Exp-Golomb bit strings and codeNum in explicit form and used as ue(v) (informative)

Bit string	codeNum
1	0
0 1 0	1
0 1 1	2
0 0 1 0 0	3
0 0 1 0 1	4
0 0 1 1 0	5
0 0 1 1 1	6
0 0 0 1 0 0 0	7
0 0 0 1 0 0 1	8
0 0 0 1 0 1 0	9
...	...

Depending on the descriptor, the value of a syntax element is derived as follows:

– If the syntax element is coded as ue(v), the value of the syntax element is equal to codeNum.

– Otherwise (the syntax element is coded as se(v)), the value of the syntax element is derived by invoking the mapping process for signed Exp-Golomb codes as specified in clause 9.2 with codeNum as input.

9.2 Mapping process for signed Exp-Golomb codes

Input to this process is codeNum as specified in clause 9.1.

Output of this process is a value of a syntax element coded as se(v).

The syntax element is assigned to the codeNum by ordering the syntax element by its absolute value in increasing order and representing the positive value for a given absolute value with the lower codeNum. Table 22 provides the assignment rule.

Table 22 – Assignment of syntax element to codeNum for signed Exp-Golomb coded syntax elements se(v)

codeNum	syntax element value
0	0
1	1
2	−1
3	2
4	−2
5	3
6	−3
k	$(-1)^{k+1}$ * Ceil(k ÷ 2)

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