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# Information technology — High efficiency coding and media delivery in heterogeneous environments —

## Part 2: High efficiency video coding

*Technologies de l'information — Codage à haute efficacité et livraison des medias dans des environnements hétérogènes —*

*Partie 2: Codage vidéo à haute efficacité*

Reference number
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## CONTENTS

## LIST OF FIGURES

## LIST OF TABLES

## Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

ISO/IEC 23008-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, in collaboration with ITU-T.

This part of ISO/IEC 23008 is technically aligned with Rec. ITU-T H.265 (04/2013) but is not published as identical text.

# 0 Introduction

## 0.1 General

This clause does not form an integral part of this Recommendation | International Standard.

## 0.2 Prologue

As the costs for both processing power and memory have reduced, network support for coded video data has diversified, and advances in video coding technology have progressed, the need has arisen for an industry standard for compressed video representation with substantially increased coding efficiency and enhanced robustness to network environments. Toward these ends the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG) formed a Joint Collaborative Team on Video Coding (JCT-VC) in 2010 for development of a new Recommendation | International Standard. This Recommendation | International Standard was developed in the JCT-VC.

## 0.3 Purpose

This Recommendation | International Standard was developed in response to the growing need for higher compression of moving pictures for various applications such as videoconferencing, digital storage media, television broadcasting, internet streaming, and communications. It is also designed to enable the use of the coded video representation in a flexible manner for a wide variety of network environments as well as to enable the use of multi-core parallel encoding and decoding devices. The use of this Recommendation | International Standard allows motion video to be manipulated as a form of computer data and to be stored on various storage media, transmitted and received over existing and future networks and distributed on existing and future broadcasting channels.

## 0.4 Applications

This Recommendation | International Standard is designed to cover a broad range of applications for video content including but not limited to the following:

- Broadcast (cable TV on optical networks / copper, satellite, terrestrial, etc.)
- Camcorders
- Content production and distribution
- Digital cinema
- Home cinema
- Internet streaming, download and play
- Medical imaging
- Mobile streaming, broadcast and communications
- Real-time conversational services (videoconferencing, videophone, telepresence, etc.)
- Remote video surveillance
- Storage media (optical disks, digital video tape recorder, etc.)
- Wireless display

## 0.5 Publication and versions of this Specification

This Specification has been jointly developed by ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). It is published as technically-aligned twin text in both ITU-T and ISO/IEC. As the basis text has been drafted to become both an ITU-T Recommendation and an ISO/IEC International Standard, the term "Specification" (with capitalization to indicate that it refers to the whole of the text) is used herein when the text refers to itself.

This is the first version of this Specification. Additional versions are anticipated.

## 0.6 Profiles, tiers and levels

This Recommendation | International Standard is designed to be generic in the sense that it serves a wide range of applications, bit rates, resolutions, qualities, and services. Applications should cover, among other things, digital storage media, television broadcasting and real-time communications. In the course of creating this Specification, various requirements from typical applications have been considered, necessary algorithmic elements have been developed, and these have been integrated into a single syntax. Hence, this Specification will facilitate video data interchange among different applications.

Considering the practicality of implementing the full syntax of this Specification, however, a limited number of subsets of the syntax are also stipulated by means of "profiles", "tiers", and "levels". These and other related terms are formally defined in clause 3.

A "profile" is a subset of the entire bitstream syntax that is specified in this Recommendation | International Standard. Within the bounds imposed by the syntax of a given profile it is still possible to require a very large variation in the performance of encoders and decoders depending upon the values taken by syntax elements in the bitstream such as the specified size of the decoded pictures. In many applications, it is currently neither practical nor economic to implement a decoder capable of dealing with all hypothetical uses of the syntax within a particular profile.

In order to deal with this problem, "tiers" and "levels" are specified within each profile. A level of a tier is a specified set of constraints imposed on values of the syntax elements in the bitstream. These constraints may be simple limits on values. Alternatively they may take the form of constraints on arithmetic combinations of values (e.g. picture width multiplied by picture height multiplied by number of pictures decoded per second). A level specified for a lower tier is more constrained than a level specified for a higher tier.

Coded video content conforming to this Recommendation | International Standard uses a common syntax. In order to achieve a subset of the complete syntax, flags, parameters, and other syntax elements are included in the bitstream that signal the presence or absence of syntactic elements that occur later in the bitstream.

## 0.7 Overview of the design characteristics

The coded representation specified in the syntax is designed to enable a high compression capability for a desired image or video quality. The algorithm is typically not lossless, as the exact source sample values are typically not preserved through the encoding and decoding processes. A number of techniques may be used to achieve highly efficient compression. Encoding algorithms (not specified in this Recommendation | International Standard) may select between inter and intra coding for block-shaped regions of each picture. Inter coding uses motion vectors for block-based inter prediction to exploit temporal statistical dependencies between different pictures. Intra coding uses various spatial prediction modes to exploit spatial statistical dependencies in the source signal for a single picture. Motion vectors and intra prediction modes may be specified for a variety of block sizes in the picture. The prediction residual may then be further compressed using a transform to remove spatial correlation inside the transform block before it is quantized, producing a possibly irreversible process that typically discards less important visual information while forming a close approximation to the source samples. Finally, the motion vectors or intra prediction modes may also be further compressed using a variety of prediction mechanisms, and, after prediction, are combined with the quantized transform coefficient information and encoded using arithmetic coding.

## 0.8 How to read this Specification

It is suggested that the reader starts with clause 1 (Scope) and moves on to clause 3 (Definitions). Clause 6 should be read for the geometrical relationship of the source, input, and output of the decoder. Clause 7 (Syntax and semantics) specifies the order to parse syntax elements from the bitstream. See subclauses 7.1–7.3 for syntactical order and see subclause 7.4 for semantics; e.g. the scope, restrictions, and conditions that are imposed on the syntax elements. The actual parsing for most syntax elements is specified in clause 9 (Parsing process). Clause 10 (Sub-bitstream extraction process) specifies the sub-bitstream extraction process. Finally, clause 8 (Decoding process) specifies how the syntax elements are mapped into decoded samples. Throughout reading this Specification, the reader should refer to clauses 2 (Normative references), 4 (Abbreviations), and 5 (Conventions) as needed. Annexes A through E also form an integral part of this Recommendation | International Standard.

Annex A specifies profiles each being tailored to certain application domains, and defines the so-called tiers and levels of the profiles. Annex B specifies syntax and semantics of a byte stream format for delivery of coded video as an ordered stream of bytes. Annex C specifies the hypothetical reference decoder, bitstream conformance, decoder conformance, and the use of the hypothetical reference decoder to check bitstream and decoder conformance. Annex D specifies syntax and semantics for supplemental enhancement information message payloads. Annex E specifies syntax and semantics of the video usability information parameters of the sequence parameter set.

Throughout this Specification, statements appearing with the preamble "NOTE –" are informative and are not an integral part of this Recommendation | International Standard.

# Information technology — High efficiency coding and media delivery in heterogeneous environments —

# Part 2: High efficiency video coding

## 1 Scope

This document specifies High efficiency video coding.

## 2 Normative references

### 2.1 General

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.

### 2.2 Identical Recommendations | International Standards

– None.

### 2.3 Paired Recommendations | International Standards equivalent in technical content

– None

### 2.4 Additional references

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

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

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

– ISO 12232: in force, *Photography – Digital still cameras – Determination of exposure index, ISO speed ratings, standard output sensitivity, and recommended exposure index*.

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

## 3 Definitions

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

**3.1 access unit**: A set of *NAL units* that are associated with each other according to a specified classification rule, are consecutive in *decoding order,* and contain exactly one *coded picture*.

NOTE 1 – In addition to containing the VCL NAL units of the coded picture, an access unit may also contain non-VCL NAL units. The decoding of an access unit always results in a decoded picture.

**3.2 AC transform coefficient**: Any *transform coefficient* for which the *frequency index* in at least one of the two dimensions is non-zero.

**3.3 associated non-VCL NAL unit**: A *non-VCL NAL unit* (when present) for a *VCL NAL unit* where the *VCL NAL unit* is the *associated VCL NAL unit* of the *non-VCL NAL unit*.

**3.4 associated IRAP picture**: The previous *IRAP picture* in *decoding order* (when present).

**3.5 associated VCL NAL unit**: The preceding *VCL NAL unit* in *decoding order* for a *non-VCL NAL unit* with nal_unit_type equal to EOS_NUT, EOB_NUT, FD_NUT, or SUFFIX_SEI_NUT, or in the ranges of

RSV_NVCL45..RSV_NVCL47 or UNSPEC56..UNSPEC63; or otherwise the next *VCL NAL unit* in *decoding order*.

**3.6** **bin**: One bit of a *bin string*.

**3.7** **binarization**: A set of *bin strings* for all possible values of a *syntax element*.

**3.8** **binarization process**: A unique mapping process of all possible values of a *syntax element* onto a set of *bin strings*.

**3.9** **bin string**: An intermediate binary representation of values of *syntax elements* from the *binarization* of the *syntax element*.

**3.10** **bi-predictive (B) slice**: A *slice* that may be decoded using *intra prediction* or *inter prediction* using at most two *motion vectors* and *reference indices* to *predict* the sample values of each *block*.

**3.11** **bitstream**: A sequence of bits, in the form of a *NAL unit stream* or a *byte stream*, that forms the representation of *coded pictures* and associated data forming one or more *CVSs*.

**3.12** **block**: An MxN (M-column by N-row) array of samples, or an MxN array of *transform coefficients*.

**3.13** **broken link**: A location in a *bitstream* at which it is indicated that some subsequent *pictures* in *decoding order* may contain serious visual artefacts due to unspecified operations performed in the generation of the *bitstream*.

**3.14** **broken link access (BLA) access unit**: An *access unit* in which the *coded picture* is a *BLA picture*.

**3.15** **broken link access (BLA) picture**: An *IRAP picture* for which each *VCL NAL unit* has nal_unit_type equal to BLA_W_LP, BLA_W_RADL, or BLA_N_LP.

NOTE 2 – A BLA picture contains only I slices, and may be the first picture in the bitstream in decoding order, or may appear later in the bitstream. Each BLA picture begins a new CVS, and has the same effect on the decoding process as an IDR picture. However, a BLA picture contains syntax elements that specify a non-empty RPS. When a BLA picture for which each VCL NAL unit has nal_unit_type equal to BLA_W_LP, it may have associated RASL pictures, which are not output by the decoder and may not be decodable, as they may contain references to pictures that are not present in the bitstream. When a BLA picture for which each VCL NAL unit has nal_unit_type equal to BLA_W_LP, it may also have associated RADL pictures, which are specified to be decoded. When a BLA picture for which each VCL NAL unit has nal_unit_type equal to BLA_W_RADL, it does not have associated RASL pictures but may have associated RADL pictures. When a BLA picture for which each VCL NAL unit has nal_unit_type equal to BLA_N_LP, it does not have any associated leading pictures.

**3.16** **buffering period**: The set of *access units* starting with an *access unit* that contains a buffering period SEI message and containing all subsequent *access units* in *decoding order* up to but not including the next *access unit* (when present) that contains a buffering period SEI message.

**3.17** **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.

**3.18** **byte-aligned**: A position in a *bitstream* is byte-aligned when the position is an integer multiple of 8 bits from the position of the first bit in the *bitstream*, and a bit or *byte* or *syntax element* is said to be byte-aligned when the position at which it appears in a *bitstream* is byte-aligned.

**3.19** **byte stream**: An encapsulation of a *NAL unit stream* containing *start code prefixes* and *NAL units* as specified in Annex B.

**3.20** **can**: A term used to refer to behaviour that is allowed, but not necessarily required.

**3.21** **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 3 – The term chroma is used rather than the term chrominance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term chrominance.

**3.22** **clean random access (CRA) access unit**: An *access unit* in which the *coded picture* is a *CRA picture*.

**3.23** **clean random access (CRA) picture**: An *IRAP picture* for which each *VCL NAL unit* has nal_unit_type equal to CRA_NUT.

NOTE 4 – A CRA picture contains only I slices, and may be the first picture in the bitstream in decoding order, or may appear later in the bitstream. A CRA picture may have associated RADL or RASL pictures. When a CRA picture has NoRaslOutputFlag equal to 1, the associated RASL pictures are not output by the decoder, because they may not be decodable, as they may contain references to pictures that are not present in the bitstream.

**3.24** **coded picture**: A *coded representation* of a *picture* containing all *coding tree units* of the *picture*.

**3.25** **coded picture buffer (CPB)**: A first-in first-out buffer containing *decoding units* in *decoding order* specified in the *hypothetical reference decoder* in Annex C.

**3.26** **coded representation**: A data element as represented in its coded form.

**3.27** **coded slice segment NAL unit**: A *NAL unit* that has nal_unit_type in the range of TRAIL_N to RASL_R, inclusive, or in the range of BLA_W_LP to RSV_IRAP_VCL23, inclusive, which indicates that the *NAL unit* contains a coded *slice segment*.

**3.28** **coded video sequence (CVS)**: A sequence of *access units* that consists, in decoding order, of an *IRAP access unit* with NoRaslOutputFlag equal to 1, followed by zero or more *access units* that are not *IRAP access units* with NoRaslOutputFlag equal to 1, including all subsequent *access units* up to but not including any subsequent *access unit* that is an *IRAP access unit* with NoRaslOutputFlag equal to 1.

NOTE 5 – An IRAP access unit may be an IDR access unit, a BLA access unit, or a CRA access unit. The value of NoRaslOutputFlag is equal to 1 for each IDR access unit, each BLA access unit, and each CRA access unit that is the first access unit in the bitstream in decoding order, is the first access unit that follows an end of sequence NAL unit in decoding order, or has HandleCraAsBlaFlag equal to 1.

**3.29** **coding block**: An NxN *block* of samples for some value of N such that the division of a *coding tree block* into *coding blocks* is a *partitioning*.

**3.30** **coding tree block**: An NxN *block* of samples for some value of N such that the division of a *component* into *coding tree blocks* is a *partitioning*.

**3.31** **coding tree unit**: A *coding tree block* of *luma* samples, two corresponding *coding tree blocks* of *chroma* samples of a *picture* that has three sample arrays, or a *coding tree block* of samples of a monochrome *picture* or a *picture* that is coded using three separate colour planes and *syntax structures* used to code the samples.

**3.32** **coding unit**: A *coding block* of *luma* samples, two corresponding *coding blocks* of *chroma* samples of a *picture* that has three sample arrays, or a *coding block* of samples of a monochrome *picture* or a *picture* that is coded using three separate colour planes and *syntax structures* used to code the samples.

**3.33** **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.

**3.34** **context variable**: A variable specified for the *adaptive binary arithmetic decoding process* of a *bin* by an equation containing recently decoded *bins*.

**3.35** **cropped decoded picture**: The result of cropping a *decoded picture* based on the conformance cropping window specified in the *SPS* that is referred to by the corresponding *coded picture*.

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

**3.37** **decoded picture buffer (DPB)**: A buffer holding *decoded pictures* for reference, output reordering, or output delay specified for the *hypothetical reference decoder* in Annex C.

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

**3.39** **decoder under test (DUT)**: A *decoder* that is tested for conformance to this Specification by operating the *hypothetical stream scheduler* to deliver a conforming *bitstream* to the *decoder* and to the *hypothetical reference decoder* and comparing the values and timing or order of the output of the two *decoders*.

**3.40** **decoding order**: The order in which *syntax elements* are processed by the *decoding process*.

**3.41** **decoding process**: The process specified in this Specification that reads a *bitstream* and derives *decoded pictures* from it.

**3.42** **decoding unit**: An *access unit* if SubPicHrdFlag is equal to 0 or a subset of an *access unit* otherwise, consisting of one or more *VCL NAL units* in an *access unit* and the *associated non-VCL NAL units*.

**3.43** **dependent slice segment**: A *slice segment* for which the values of some *syntax elements* of the *slice segment header* are inferred from the values for the preceding *independent slice segment* in *decoding order*.

**3.44** **display process**: A process not specified in this Specification having, as its input, the *cropped decoded pictures* that are the output of the *decoding process*.

**3.45** **elementary stream**: A sequence of one or more *bitstreams*.

NOTE 6 – An elementary stream that consists of two or more bitstreams would typically have been formed by splicing together two or more bitstreams (or parts thereof).

3.46 **emulation prevention byte**: A *byte* equal to 0x03 that is present within a *NAL unit* when the *syntax elements* of the *bitstream* form certain patterns of *byte* values in a manner that ensures that no sequence of consecutive *byte-aligned bytes* in the *NAL unit* can contain a *start code prefix*.

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

3.48 **encoding process**: A process not specified in this Specification that produces a *bitstream* conforming to this Specification.

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

3.50 **filler data NAL units**: *NAL units* with nal_unit_type equal to FD_NUT.

3.51 **flag**: A variable that can take one of the two possible values 0 and 1.

3.52 **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*.

3.53 **frequency index**: A one-dimensional or two-dimensional index associated with a *transform coefficient* prior to an *inverse transform* part of the *decoding process*.

3.54 **hypothetical reference decoder (HRD)**: A hypothetical *decoder* model that specifies constraints on the variability of conforming *NAL unit streams* or conforming *byte streams* that an encoding process may produce.

3.55 **hypothetical stream scheduler (HSS)**: A hypothetical delivery mechanism used for checking the conformance of a *bitstream* or a *decoder* with regards to the timing and data flow of the input of a *bitstream* into the *hypothetical reference decoder*.

3.56 **independent slice segment**: A *slice segment* for which the values of the *syntax elements* of the *slice segment header* are not inferred from the values for a preceding *slice segment*.

3.57 **informative**: A term used to refer to content provided in this Specification that does not establish any mandatory requirements for conformance to this Specification and thus is not considered an integral part of this Specification.

3.58 **instantaneous decoding refresh (IDR) access unit**: An *access unit* in which the *coded picture* is an *IDR picture*.

3.59 **instantaneous decoding refresh (IDR) picture**: An *IRAP picture* for which each *VCL NAL unit* has nal_unit_type equal to IDR_W_RADL or IDR_N_LP.

NOTE 7 – An IDR picture contains only I slices, and may be the first picture in the bitstream in decoding order, or may appear later in the bitstream. Each IDR picture is the first picture of a CVS in decoding order. When an IDR picture for which each VCL NAL unit has nal_unit_type equal to IDR_W_RADL, it may have associated RADL pictures. When an IDR picture for which each VCL NAL unit has nal_unit_type equal to IDR_N_LP, it does not have any associated leading pictures. An IDR picture does not have associated RASL pictures.

3.60 **inter coding**: Coding of a *coding block*, *slice*, or *picture* that uses *inter prediction*.

3.61 **inter prediction**: A *prediction* derived in a manner that is dependent on data elements (e.g. sample values or motion vectors) of *pictures* other than the current *picture*.

3.62 **intra coding**: Coding of a *coding block, slice*, or *picture* that uses *intra prediction*.

3.63 **intra prediction**: A *prediction* derived from only data elements (e.g. sample values) of the same decoded *slice*.

3.64 **intra random access point (IRAP) access unit**: An *access unit* in which the *coded picture* is an *IRAP picture*.

3.65 **intra random access point (IRAP) picture**: A coded *picture* for which each *VCL NAL unit* has nal_unit_type in the range of BLA_W_LP to RSV_IRAP_VCL23, inclusive.

NOTE 8 – An IRAP picture contains only I slices, and may be a BLA picture, a CRA picture or an IDR picture. The first picture in the bitstream in decoding order must be an IRAP picture. Provided the necessary parameter sets are available when they need to be activated, the IRAP picture and all subsequent non-RASL pictures in decoding order can be correctly decoded without performing the decoding process of any pictures that precede the IRAP picture in decoding order. There may be pictures in a bitstream that contain only I slices that are not IRAP pictures.

3.66 **intra (I) slice**: A *slice* that is decoded using *intra prediction* only.

3.67 **inverse transform**: A part of the *decoding process* by which a set of *transform coefficients* are converted into spatial-domain values.

3.68 **layer**: A set of *VCL NAL units* that all have a particular value of nuh_layer_id and the *associated non-VCL NAL units*, or one of a set of syntactical structures having a hierarchical relationship.

NOTE 9 – Depending on the context, either the first layer concept or the second layer concept applies. The first layer concept is also referred to as a scalable layer, wherein a layer may be a spatial scalable layer, a quality scalable layer, a view, etc. A temporal true subset of a scalable layer is not referred to as a layer but referred to as a sub-layer or temporal sub-layer. The second layer concept is also referred to as a coding layer, wherein higher layers contain lower layers, and the coding layers are the CVS, picture, slice, slice segment, and coding tree unit layers.

**3.69** **layer identifier list**: A list of nuh_layer_id values that is associated with a *layer set* or an *operation point* and can be used as an input to the *sub-bitstream extraction process*.

**3.70** **layer set**: A set of *layers* represented within a *bitstream* created from another *bitstream* by operation of the *sub-bitstream extraction process* with the another *bitstream*, the target highest TemporalId equal to 6, and the target *layer identifier list* equal to the *layer identifier list* associated with the layer set as inputs.

**3.71** **leading picture**: A *picture* that precedes the *associated IRAP picture* in *output order*.

**3.72** **leaf**: A terminating node of a tree that is a root node of a tree of depth 0.

**3.73** **level**: A defined set of constraints on the values that may be taken by the *syntax elements* and variables of this Specification, or the value of a *transform coefficient* prior to *scaling*.

NOTE 10 – The same set of levels is defined for all profiles, with most aspects of the definition of each level being in common across different profiles. Individual implementations may, within the specified constraints, support a different level for each supported profile.

**3.74** **list 0 (list 1) motion vector**: A *motion vector* associated with a *reference index* pointing into *reference picture list 0* (*list 1*).

**3.75** **list 0 (list 1) prediction**: *Inter prediction* of the content of a *slice* using a *reference index* pointing into *reference picture list 0* (*list 1*).

**3.76** **long-term reference picture**: A *picture* that is marked as "used for long-term reference".

**3.77** **long-term reference picture set**: The two RPS lists that may contain long-term reference pictures.

**3.78** **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 11 – The term luma is used rather than the term luminance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term luminance. The symbol L is sometimes used instead of the symbol Y to avoid confusion with the symbol y as used for vertical location.

**3.79** **may**: A term that is used to refer to behaviour that is allowed, but not necessarily required.

NOTE 12 – In some places where the optional nature of the described behaviour is intended to be emphasized, the phrase "may or may not" is used to provide emphasis.

**3.80** **motion vector**: A two-dimensional vector used for *inter prediction* that provides an offset from the coordinates in the *decoded picture* to the coordinates in a *reference picture*.

**3.81** **must**: A term that is used in expressing an observation about a requirement or an implication of a requirement that is specified elsewhere in this Specification (used exclusively in an *informative* context).

**3.82** **nested SEI message**: An SEI message that is contained in a scalable nesting SEI message.

**3.83** **network abstraction layer (NAL) unit**: A *syntax structure* containing an indication of the type of data to follow and *bytes* containing that data in the form of an *RBSP* interspersed as necessary with *emulation prevention bytes*.

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

**3.85** **non-nested SEI message**: An SEI message that is not contained in a scalable nesting SEI message.

**3.86** **non-reference picture**: A *picture* that is marked as "unused for reference".

NOTE 13 – A non-reference picture contains samples that cannot be used for inter prediction in the decoding process of subsequent pictures in decoding order. In other words, once a picture is marked as "unused for reference", it can never be marked back as "used for reference".

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

**3.88** **note**: A term that is used to prefix *informative* remarks (used exclusively in an *informative* context).

**3.89** **operation point**: A *bitstream* created from another *bitstream* by operation of the *sub-bitstream extraction process* with the another *bitstream*, a target highest TemporalId, and a target *layer identifier list* as inputs.

NOTE 14 – If the target highest TemporalId of an operation point is equal to the greatest value of TemporalId in the layer set associated with the target layer identification list, the operation point is identical to the layer set. Otherwise it is a subset of the layer set.

3.90 **output order**: The order in which the *decoded pictures* are output from the *decoded picture buffer* (for the *decoded pictures* that are to be output from the *decoded picture buffer*).

3.91 **parameter**: A *syntax element* of a *VPS, SPS* or *PPS*, or the second word of the defined term *quantization parameter*.

3.92 **partitioning**: The division of a set into subsets such that each element of the set is in exactly one of the subsets.

3.93 **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 15 – A picture may be either a frame or a field. However, in one CVS, either all pictures are frames or all pictures are fields.

3.94 **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* found in each *slice segment header*.

3.95 **picture order count**: A variable that is associated with each *picture*, uniquely identifies the associated *picture* among all *pictures* in the *CVS*, and, when the associated *picture* is to be output from the *decoded picture buffer*, indicates the position of the associated *picture* in *output order* relative to the *output order* positions of the other *pictures* in the same *CVS* that are to be output from the *decoded picture buffer*.

3.96 **prediction**: An embodiment of the *prediction process*.

3.97 **prediction block**: A rectangular MxN *block* of samples on which the same *prediction* is applied.

3.98 **prediction process**: The use of a *predictor* to provide an estimate of the data element (e.g. sample value or motion vector) currently being decoded.

3.99 **prediction unit**: A *prediction block* of *luma* samples, two corresponding *prediction blocks* of *chroma* samples of a *picture* that has three sample arrays, or a *prediction block* of samples of a monochrome *picture* or a *picture* that is coded using three separate colour planes and *syntax structures* used to predict the *prediction block* samples.

3.100 **predictive (P) slice**: A *slice* that may be decoded using *intra prediction* or *inter prediction* using at most one *motion vector* and *reference index* to *predict* the sample values of each *block*.

3.101 **predictor**: A combination of specified values or previously decoded data elements (e.g. sample value or motion vector) used in the *decoding process* of subsequent data elements.

3.102 **prefix SEI message**: An SEI message that is contained in a *prefix SEI NAL unit*.

3.103 **prefix SEI NAL unit**: An *SEI NAL unit* that has nal_unit_type equal to PREFIX_SEI_NUT.

3.104 **profile**: A specified subset of the syntax of this Specification.

3.105 **quadtree**: A *tree* in which a parent node can be split into four child nodes, each of which may become parent node for another split into four child nodes.

3.106 **quantization parameter**: A variable used by the *decoding process* for *scaling* of *transform coefficient levels*.

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

3.108 **random access decodable leading (RADL) access unit**: An *access unit* in which the *coded picture* is a *RADL picture*.

3.109 **random access decodable leading (RADL) picture**: A *coded picture* for which each *VCL NAL unit* has nal_unit_type equal to RADL_R or RADL_N.

NOTE 16 – All RADL pictures are leading pictures. RADL pictures are not used as reference pictures for the decoding process of trailing pictures of the same associated IRAP picture. When present, all RADL pictures precede, in decoding order, all trailing pictures of the same associated IRAP picture.

3.110 **random access skipped leading (RASL) access unit**: An *access unit* in which the *coded picture* is a *RASL picture.*

3.111 **random access skipped leading (RASL) picture**: A *coded picture* for which each *VCL NAL unit* has nal_unit_type equal to RASL_R or RASL_N.

NOTE 17 – All RASL pictures are leading pictures of an associated BLA or CRA picture. When the associated IRAP picture has NoRaslOutputFlag equal to 1, the RASL picture is not output and may not be correctly decodable, as the RASL picture may contain references to pictures that are not present in the bitstream. RASL pictures are not used as reference pictures for the decoding process of non-RASL pictures. When present, all RASL pictures precede, in decoding order, all trailing pictures of the same associated IRAP picture.

**3.112** **raster scan**: A mapping of a rectangular two-dimensional pattern to a one-dimensional pattern such that the first entries in the one-dimensional pattern are from the first top row of the two-dimensional pattern scanned from left to right, followed similarly by the second, third, etc., rows of the pattern (going down) each scanned from left to right.

**3.113** **raw byte sequence payload (RBSP)**: A *syntax structure* containing an integer number of *bytes* that is encapsulated in a *NAL unit* and that is either empty or has the form of a *string of data bits* containing *syntax elements* followed by an *RBSP stop bit* and zero or more subsequent bits equal to 0.

**3.114** **raw byte sequence payload (RBSP) stop bit**: A bit equal to 1 present within a *raw byte sequence payload (RBSP)* after a *string of data bits*, for which the location of the end within an *RBSP* can be identified by searching from the end of the *RBSP* for the *RBSP stop bit*, which is the last non-zero bit in the *RBSP*.

**3.115** **recovery point**: A point in the *bitstream* at which the recovery of an exact or an approximate representation of the *decoded pictures* represented by the *bitstream* is achieved after a *random access* or *broken link*.

**3.116** **reference index**: An index into a *reference picture list*.

**3.117** **reference picture**: A *picture* that is a *short-term reference picture* or a *long-term reference picture*.

NOTE 18 – A reference picture contains samples that may be used for inter prediction in the decoding process of subsequent pictures in decoding order.

**3.118** **reference picture list**: A list of *reference pictures* that is used for *inter prediction* of a *P* or *B slice.*

NOTE 19 – For the decoding process of a P slice, there is one reference picture list – reference picture list 0. For the decoding process of a B slice, there are two reference picture lists – reference picture list 0 and reference picture list 1.

**3.119** **reference picture list 0**: The *reference picture list* used for *inter prediction* of a *P* or the first *reference picture list* used for *inter prediction* of a *B slice*.

**3.120** **reference picture list 1**: The second *reference picture list* used for *inter prediction* of a *B slice*.

**3.121** **reference picture set (RPS)**: A set of *reference pictures* associated with a *picture*, consisting of all *reference pictures* that are prior to the associated *picture* in decoding order, that may be used for *inter prediction* of the associated *picture* or any *picture* following the associated *picture* in *decoding order*.

NOTE 20 – The RPS of a picture consists of five RPS lists, three of which are to contain short-term reference pictures and the other two are to contain long-term reference pictures.

**3.122** **reserved**: A term that may be 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 *bitstreams* conforming to this version of this Specification, but may be used in bitstreams conforming to future extensions of this Specification by ITU-T | ISO/IEC.

**3.123** **residual**: The decoded difference between a *prediction* of a sample or data element and its decoded value.

**3.124** **sample aspect ratio**: The ratio between the intended horizontal distance between the columns and the intended vertical distance between the rows of the *luma* sample array in a *picture*, which is specified for assisting the *display process* (not specified in this Specification) and expressed as *h*:*v*, where *h* is the horizontal width and *v* is the vertical height, in arbitrary units of spatial distance.

**3.125** **scaling**: The process of multiplying *transform coefficient levels* by a factor, resulting in *transform coefficients*.

**3.126** **sequence parameter set (SPS)**: A *syntax structure* containing *syntax elements* that apply to zero or more entire *CVSs* as determined by the content of a *syntax element* found in the *PPS* referred to by a *syntax element* found in each *slice segment header*.

**3.127** **shall**: A term used to express mandatory requirements for conformance to this Specification.

NOTE 21 – When used to express a mandatory constraint on the values of syntax elements or on the results obtained by operation of the specified decoding process, it is the responsibility of the encoder to ensure that the constraint is fulfilled. When used in reference to operations performed by the decoding process, any decoding process that produces identical cropped decoded pictures to those output from the decoding process described in this Specification conforms to the decoding process requirements of this Specification.

**3.128** **short-term reference picture**: A *picture* that is marked as "used for short-term reference".

**3.129** **short-term reference picture set**: The three RPS lists that may contain short-term reference pictures.

**3.130** **should**: A term 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.

**3.131** **slice**: An integer number of *coding tree units* contained in one *independent slice segment* and all subsequent *dependent slice segments* (if any) that precede the next *independent slice segment* (if any) within the same *access unit*.

**3.132** **slice header**: The *slice segment header* of the *independent slice segment* that is a current *slice segment* or the most recent *independent slice segment* that precedes a current *dependent slice segment* in *decoding order*.

**3.133** **slice segment**: An integer number of *coding tree units* ordered consecutively in the *tile scan* and contained in a single *NAL unit*.

**3.134** **slice segment header**: A part of a coded *slice segment* containing the data elements pertaining to the first or all *coding tree units* represented in the *slice segment*.

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

**3.136** **start code prefix**: A unique sequence of three *bytes* equal to 0x000001 embedded in the *byte stream* as a prefix to each *NAL unit*.

NOTE 22 – The location of a start code prefix can be used by a decoder to identify the beginning of a new NAL unit and the end of a previous NAL unit. Emulation of start code prefixes is prevented within NAL units by the inclusion of emulation prevention bytes.

**3.137** **step-wise temporal sub-layer access (STSA) access unit**: An *access unit* in which the *coded picture* is an *STSA picture*.

**3.138** **step-wise temporal sub-layer access (STSA) picture**: A *coded picture* for which each *VCL NAL unit* has nal_unit_type equal to STSA_R or STSA_N.

NOTE 23 – An STSA picture does not use pictures with the same TemporalId as the STSA picture for inter prediction reference. Pictures following an STSA picture in decoding order with the same TemporalId as the STSA picture do not use pictures prior to the STSA picture in decoding order with the same TemporalId as the STSA picture for inter prediction reference. An STSA picture enables up-switching, at the STSA picture, to the sub-layer containing the STSA picture, from the immediately lower sub-layer. STSA pictures must have TemporalId greater than 0.

**3.139** **string of data bits (SODB)**: A sequence of some number of bits representing *syntax elements* present within a *raw byte sequence payload* prior to the *raw byte sequence payload stop bit*, 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.

**3.140** **sub-bitstream extraction process**: A specified process by which *NAL units* in a *bitstream* that do not belong to a target set, determined by a target highest TemporalId and a target *layer identifier list*, are removed from the *bitstream*, with the output sub-bitstream consisting of the NAL units in the *bitstream* that belong to the target set.

**3.141** **sub-layer**: A temporal scalable layer of a temporal scalable *bitstream*, consisting of *VCL NAL units* with a particular value of the TemporalId variable and the associated *non-VCL NAL units*.

**3.142** **sub-layer non-reference picture**: A *picture* that contains samples that cannot be used for *inter prediction* in the *decoding process* of subsequent *pictures* of the same *sub-layer* in *decoding order*.

NOTE 24 – Samples of a sub-layer non-reference picture may be used for inter prediction in the decoding process of subsequent pictures of higher sub-layers in decoding order.

**3.143** **sub-layer reference picture**: A *picture* that contains samples that may be used for *inter prediction* in the *decoding process* of subsequent *pictures* of the same *sub-layer* in *decoding order*.

NOTE 25 – Samples of a sub-layer reference picture may also be used for inter prediction in the decoding process of subsequent pictures of higher sub-layers in decoding order.

**3.144** **sub-layer representation**: A subset of the *bitstream* consisting of *NAL units* of a particular *sub-layer* and the lower *sub-layers*.

**3.145** **suffix SEI message**: An SEI message that is contained in a *suffix SEI NAL unit*.

**3.146** **suffix SEI NAL unit**: An *SEI NAL unit* that has nal_unit_type equal to SUFFIX_SEI_NUT.

**3.147** **supplemental enhancement information (SEI) NAL unit**: A *NAL unit* that has nal_unit_type equal to PREFIX_SEI_NUT or SUFFIX_SEI_NUT.

**3.148** **syntax element**: An element of data represented in the *bitstream*.

**3.149** **syntax structure**: Zero or more *syntax elements* present together in the *bitstream* in a specified order.

3.150 **temporal sub-layer access (TSA) access unit**: An *access unit* in which the *coded picture* is a *TSA picture*.

3.151 **temporal sub-layer access (TSA) picture**: A *coded picture* for which each *VCL NAL unit* has nal_unit_type equal to TSA_R or TSA_N.

NOTE 26 – A TSA picture and pictures following the TSA picture in decoding do not use pictures with TemporalId greater than or equal to that of the TSA picture for inter prediction reference. A TSA picture enables up-switching, at the TSA picture, to the sub-layer containing the TSA picture or any higher sub-layer, from the immediately lower sub-layer. TSA pictures must have TemporalId greater than 0.

3.152 **temporal sub-layer**: A temporal scalable layer of a temporal scalable *bitstream*, consisting of *VCL NAL units* with a particular value of TemporalId and the associated *non-VCL NAL units*.

3.153 **tier**: A specified category of *level* constraints imposed on values of the *syntax elements* in the *bitstream*, where the *level* contraints are nested within a *tier* and a *decoder* conforming to a certain *tier* and *level* would be capable of decoding all *bitstreams* that conform to the same *tier* or the lower *tier* of that *level* or any *level* below it.

3.154 **tile**: A rectangular region of *coding tree blocks* within a particular *tile column* and a particular *tile row* in a *picture*.

3.155 **tile column**: A rectangular region of *coding tree blocks* having a height equal to the height of the *picture* and a width specified by *syntax elements* in the *picture parameter set*.

3.156 **tile row**: A rectangular region of *coding tree blocks* having a height specified by *syntax elements* in the *picture parameter set* and a width equal to the width of the *picture*.

3.157 **tile scan**: A specific sequential ordering of *coding tree blocks partitioning* a *picture* in which the *coding tree blocks* are ordered consecutively in *coding tree block raster scan* in a *tile* whereas *tiles* in a *picture* are ordered consecutively in a *raster scan* of the *tiles* of the *picture*.

3.158 **trailing picture**: A *picture* that follows the *associated IRAP picture* in *output order*.

NOTE 27 – Trailing pictures associated with an IRAP picture also follow the IRAP picture in decoding order. Pictures that follow the associated IRAP picture in output order and precede the associated IRAP picture in decoding order are not allowed.

3.159 **transform block**: A rectangular MxN *block* of samples on which the same *transform* is applied.

3.160 **transform coefficient**: A scalar quantity, considered to be in a frequency domain, that is associated with a particular one-dimensional or two-dimensional *frequency index* in an *inverse transform* part of the *decoding process*.

3.161 **transform coefficient level**: An integer quantity representing the value associated with a particular two-dimensional frequency index in the *decoding process* prior to *scaling* for computation of a *transform coefficient* value.

3.162 **transform unit**: A *transform block* of *luma* samples of size 8x8, 16x16, or 32x32 or four *transform blocks* of *luma samples* of size 4x4, two corresponding *transform blocks* of *chroma* samples of a *picture* that has three sample arrays, or a *transform block* of *luma* samples of size 8x8, 16x16, or 32x32 or four *transform blocks* of *luma samples* of size 4x4 of a monochrome *picture* or a *picture* that is coded using three separate colour planes and *syntax structures* used to transform the *transform block* samples.

3.163 **tree**: A tree is a finite set of nodes with a unique root node.

3.164 **universal unique identifier (UUID)**: An identifier that is unique with respect to the space of all universal unique identifiers.

3.165 **unspecified**: A term that may be used to specify some values of a particular *syntax element* to indicate that the values have no specified meaning in this Specification and will not have a specified meaning in the future as an integral part of future versions of this Specification.

3.166 **video coding layer (VCL) NAL unit**: A collective term for *coded slice segment NAL units* and the subset of *NAL units* that have *reserved* values of nal_unit_type that are classified as VCL NAL units in this Specification.

3.167 **video parameter set (VPS)**: A *syntax structure* containing *syntax elements* that apply to zero or more entire *CVSs* as determined by the content of a *syntax element* found in the *SPS* referred to by a *syntax element* found in the *PPS* referred to by a *syntax element* found in each *slice segment header*.

3.168 **z-scan order**: A specified sequential ordering of *blocks partitioning* a *picture*, where the order is identical to *coding tree block raster scan* of the *picture* when the *blocks* are of the same size as *coding tree blocks*, and, when the *blocks* are of a smaller size than *coding tree blocks*, i.e. *coding tree blocks* are further partitioned into smaller *coding blocks*, the order traverses from *coding tree block* to *coding tree block* in *coding tree block raster scan* of the *picture*, and inside each *coding tree block*, which may be divided into *quadtrees* hierarchically to lower levels, the order traverses from *quadtree* to *quadtree* of a particular level in *quadtree*-of-the-particular-level *raster scan* of the *quadtree* of the immediately higher level.

## 4 Abbreviations

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

| | |
|---|---|
| B | Bi-predictive |
| BLA | Broken Link Access |
| CABAC | Context-based Adaptive Binary Arithmetic Coding |
| CB | Coding Block |
| CBR | Constant Bit Rate |
| CRA | Clean Random Access |
| CPB | Coded Picture Buffer |
| CTB | Coding Tree Block |
| CTU | Coding Tree Unit |
| CU | Coding Unit |
| CVS | Coded Video Sequence |
| DPB | Decoded Picture Buffer |
| DUT | Decoder Under Test |
| EG | Exponential-Golomb |
| FIFO | First-In, First-Out |
| FIR | Finite Impulse Response |
| FL | Fixed-Length |
| GDR | Gradual Decoding Refresh |
| HRD | Hypothetical Reference Decoder |
| HSS | Hypothetical Stream Scheduler |
| I | Intra |
| IDR | Instantaneous Decoding Refresh |
| IRAP | Intra Random Access Point |
| LPS | Least Probable Symbol |
| LSB | Least Significant Bit |
| MPS | Most Probable Symbol |
| MSB | Most Significant Bit |
| NAL | Network Abstraction Layer |
| P | Predictive |
| PB | Prediction Block |
| PPS | Picture Parameter Set |
| PU | Prediction Unit |
| RADL | Random Access Decodable Leading (Picture) |
| RASL | Random Access Skipped Leading (Picture) |

| | |
|---|---|
| RBSP | Raw Byte Sequence Payload |
| RPS | Reference Picture Set |
| SEI | Supplemental Enhancement Information |
| SODB | String Of Data Bits |
| SPS | Sequence Parameter Set |
| STSA | Step-wise Temporal Sub-layer Access |
| TB | Transform Block |
| TR | Truncated Rice |
| TSA | Temporal Sub-layer Access |
| TU | Transform Unit |
| UUID | Universal Unique Identifier |
| VBR | Variable Bit Rate |
| VCL | Video Coding Layer |
| VPS | Video Parameter Set |
| VUI | Video Usability Information |

# 5 Conventions

## 5.1 General

NOTE – 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.

## 5.2 Arithmetic operators

The following arithmetic operators are defined as follows:

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

## 5.3 Logical operators

The following logical operators are defined as follows:

| | |
|---|---|
| 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

The following relational operators are defined as follows:

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

When a relational operator is applied to a 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

The following bit-wise operators are defined as follows:

| | |
|---|---|
| & | Bit-wise "and". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0. |
| \| | Bit-wise "or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0. |
| ^ | Bit-wise "exclusive or". When operating on integer arguments, operates on a two's complement representation of the integer value. When operating on a binary argument that contains fewer bits than another argument, the shorter argument is extended by adding more significant bits equal to 0. |
| x >> y | Arithmetic right shift of a two's complement integer representation of x by y binary digits. This function is defined only for non-negative integer values of y. Bits shifted into the 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 LSBs as a result of the left shift have a value equal to 0. |

## 5.6 Assignment operators

The following arithmetic operators are defined as follows:

| | |
|---|---|
| = | 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

The following notation is used to specify a range of values:

| | |
|---|---|
| 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

The following mathematical functions are defined:

$$\text{Abs}(\ x\ ) = \begin{cases} x & ; \quad x >= 0 \\ -x & ; \quad x < 0 \end{cases} \tag{5-1}$$

Ceil( x ) the smallest integer greater than or equal to x. (5-2)

$$\text{Clip1}_Y(\ x\ ) = \text{Clip3}(\ 0, (\ 1\ <<\ \text{BitDepth}_Y\ ) - 1, x\ ) \tag{5-3}$$

$$\text{Clip1}_C(\ x\ ) = \text{Clip3}(\ 0, (\ 1\ <<\ \text{BitDepth}_C\ ) - 1, x\ ) \tag{5-4}$$

$$\text{Clip3}(\ x, y, z\ ) = \begin{cases} x & ; \quad z < x \\ y & ; \quad z > y \\ z & ; \quad \text{otherwise} \end{cases} \tag{5-5}$$

Floor( x ) the largest integer less than or equal to x. (5-6)

Log2( x ) the base-2 logarithm of x. (5-7)

Log10( x )the base-10 logarithm of x. (5-8)

$$\text{Min}(\ x, y\ ) = \begin{cases} x & ; \quad x <= y \\ y & ; \quad x > y \end{cases} \tag{5-9}$$

$$\text{Max}(\ x, y\ ) = \begin{cases} x & ; \quad x >= y \\ y & ; \quad x < y \end{cases} \tag{5-10}$$

$$\text{Round}(\ x\ ) = \text{Sign}(\ x\ ) * \text{Floor}(\ \text{Abs}(\ x\ ) + 0.5\ ) \tag{5-11}$$

$$\text{Sign}(\ x\ ) = \begin{cases} 1 & ; \quad x > 0 \\ 0 & ; \quad x = 0 \\ -1 & ; \quad x < 0 \end{cases} \tag{5-12}$$

$$\text{Sqrt}(\ x\ ) = \sqrt{x} \tag{5-13}$$

$$\text{Swap}(\ x, y\ ) = (\ y, x\ ) \tag{5-14}$$

## 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 5-1 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 5-1 – 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), "$\sum_{i=x}^{y} f(i)$" |
| "x << y", "x >> y" |
| "x < y", "x <= y", "x > y", "x >= y" |
| "x = = y", "x != y" |
| "x & y" |
| "x \| y" |
| "x && y" |
| "x \|\| y" |
| "x ? y : z" |
| "x..y" |
| "x = y", "x += y", "x −= y" |

## 5.10 Variables, syntax elements, and tables

Syntax elements in the bitstream 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 may use the values of other variables derived from syntax elements values. 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 may 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 subclause 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 may 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 bitstream are referred to as syntax functions. These functions are specified in subclause 7.2 and assume the existence of a bitstream pointer with an indication of the position of the next bit to be read by the decoding process from the bitstream. 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 subclause 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 may be denoted either as s[ x ][ y ] or as $s_{yx}$. A single column of a matrix may 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 may be referred to as the list s[ x ].

A specification of values of the entries in rows and columns of an array may 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", may be used 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
```

may be 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
```

may be 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
```

may be 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 may 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.

In the specification of a process, a specific coding block may be referred to by the variable name having a value equal to the address of the specific coding block.

# 6 Bitstream and picture formats, partitionings, scanning processes, and neighbouring relationships

## 6.1 Bitstream formats

This subclause specifies the relationship between the NAL unit stream and byte stream, either of which are referred to as the bitstream.

The bitstream can be in one of two formats: the NAL unit stream format or the byte stream format. The NAL unit stream format is conceptually the more "basic" type. It consists of a sequence of syntax structures called NAL units. This sequence is ordered in decoding order. There are constraints imposed on the decoding order (and contents) of the NAL units in the NAL unit stream.

The byte stream format can be constructed from the NAL unit stream format by ordering the NAL units in decoding order and prefixing each NAL unit with a start code prefix and zero or more zero-valued bytes to form a stream of bytes. The NAL unit stream format can be extracted from the byte stream format by searching for the location of the unique start code prefix pattern within this stream of bytes. Methods of framing the NAL units in a manner other than use of the byte stream format are outside the scope of this Specification. The byte stream format is specified in Annex B.

## 6.2 Source, decoded, and output picture formats

This subclause specifies the relationship between source and decoded pictures that is given via the bitstream.

The video source that is represented by the bitstream is a sequence of pictures in decoding order.

The source and decoded pictures are each comprised of one or more sample arrays:

- Luma (Y) only (monochrome).

– Luma and two chroma (YCbCr or YCgCo).
– Green, Blue and Red (GBR, also known as RGB).
– Arrays representing other unspecified monochrome or tri-stimulus colour samplings (for example, YZX, also known as XYZ).

For convenience of notation and terminology in this Specification, the variables and terms associated with these arrays are referred to as luma (or L or Y) and chroma, where the two chroma arrays are referred to as Cb and Cr; regardless of the actual colour representation method in use. The actual colour representation method in use can be indicated in syntax that is specified in Annex E.

The variables SubWidthC, and SubHeightC are specified in Table 6-1, depending on the chroma format sampling structure, which is specified through chroma_format_idc and separate_colour_plane_flag. Other values of chroma_format_idc, SubWidthC, and SubHeightC may be specified in the future by ITU-T | ISO/IEC.

**Table 6-1 – SubWidthC, and SubHeightC values derived from chroma_format_idc and separate_colour_plane_flag**

| chroma_format_idc | separate_colour_plane_flag | Chroma format | SubWidthC | SubHeightC |
|---|---|---|---|---|
| 0 | 0 | monochrome | 1 | 1 |
| 1 | 0 | 4:2:0 | 2 | 2 |
| 2 | 0 | 4:2:2 | 2 | 1 |
| 3 | 0 | 4:4:4 | 1 | 1 |
| 3 | 1 | 4:4:4 | 1 | 1 |

In monochrome sampling there is only one sample array, which is nominally considered the luma array.

In 4:2:0 sampling, each of the two chroma arrays has half the height and half the width of the luma array.

In 4:2:2 sampling, each of the two chroma arrays has the same height and half the width of the luma array.

In 4:4:4 sampling, depending on the value of separate_colour_plane_flag, the following applies:

– If separate_colour_plane_flag is equal to 0, each of the two chroma arrays has the same height and width as the luma array.
– Otherwise (separate_colour_plane_flag is equal to 1), the three colour planes are separately processed as monochrome sampled pictures.

The number of bits necessary for the representation of each of the samples in the luma and chroma arrays in a video sequence is in the range of 8 to 14, inclusive, and the number of bits used in the luma array may differ from the number of bits used in the chroma arrays.

When the value of chroma_format_idc is equal to 1, the nominal vertical and horizontal relative locations of luma and chroma samples in pictures are shown in Figure 6-1. Alternative chroma sample relative locations may be indicated in video usability information (see Annex E).

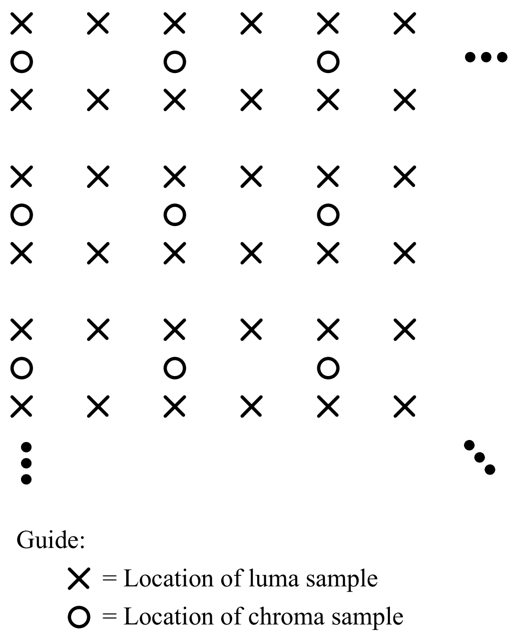


**Figure 6-1 – Nominal vertical and horizontal locations of 4:2:0 luma and chroma samples in a picture**

When the value of chroma_format_idc is equal to 2, the chroma samples are co-sited with the corresponding luma samples and the nominal locations in a picture are as shown in Figure 6-2.

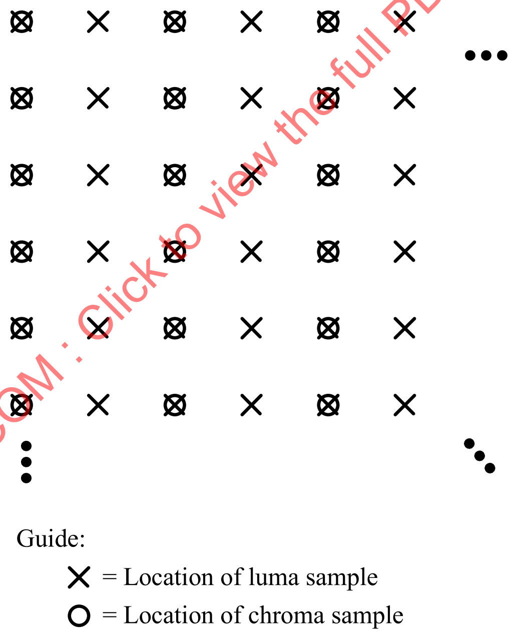
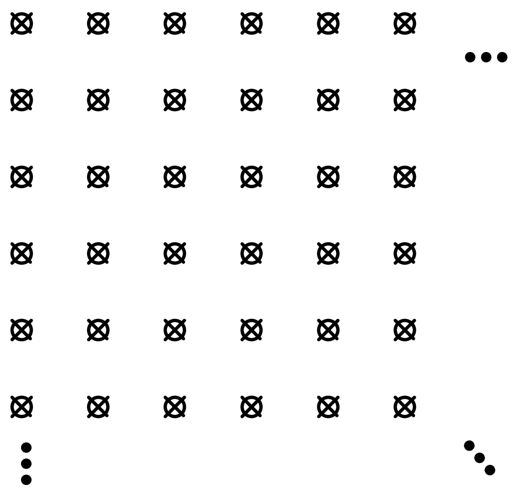


**Figure 6-2 – Nominal vertical and horizontal locations of 4:2:2 luma and chroma samples in a picture**

When the value of chroma_format_idc is equal to 3, all array samples are co-sited for all cases of pictures and the nominal locations in a picture are as shown in Figure 6-3.



Guide:

✕ = Location of luma sample

○ = Location of chroma sample

**Figure 6-3 – Nominal vertical and horizontal locations of 4:4:4 luma and chroma samples in a picture**

## 6.3 Partitioning of pictures, slices, slice segments, tiles, coding tree units, and coding tree blocks

### 6.3.1 Partitioning of pictures into slices, slice segments, and tiles

This subclause specifies how a picture is partitioned into slices, slice segments, and tiles. Pictures are divided into slices and tiles. A slice is a sequence of one or more slice segments starting with an independent slice segment and containing all subsequent dependent slice segments (if any) that precede the next independent slice segment (if any) within the same access unit. A slice segment is a sequence of coding tree units. Likewise, a tile is a sequence of coding tree units.

For example, a picture may be divided into two slices as shown in Figure 6-4. In this example, the first slice is composed of an independent slice segment containing 4 coding tree units, a dependent slice segment containing 32 coding tree units, and another dependent slice segment containing 24 coding tree units; and the second slice consists of a single independent slice segment containing the remaining 39 coding tree units of the picture.

As another example, a picture may be divided into two tiles separated by a vertical tile boundary as shown in Figure 6-5. The left side of the figure illustrates a case in which the picture only contains one slice, starting with an independent slice segment and followed by four dependent slice segments. The right side of the figure illustrates an alternative case in which the picture contains two slices in the first tile and one slice in the second tile.

Unlike slices, tiles are always rectangular. A tile always contains an integer number of coding tree units, and may consist of coding tree units contained in more than one slice. Similarly, a slice may consist of coding tree units contained in more than one tile.

One or both of the following conditions shall be fulfilled for each slice and tile:

– All coding tree units in a slice belong to the same tile.

– All coding tree units in a tile belong to the same slice.

NOTE 1 – Within the same picture, there may be both slices that contain multiple tiles and tiles that contain multiple slices.

One or both of the following conditions shall be fulfilled for each slice segment and tile:

– All coding tree units in a slice segment belong to the same tile.

– All coding tree units in a tile belong to the same slice segment.

When a picture is coded using three separate colour planes (separate_colour_plane_flag is equal to 1), a slice contains only coding tree blocks of one colour component being identified by the corresponding value of colour_plane_id, and each colour component array of a picture consists of slices having the same colour_plane_id value. Coded slices with different values of colour_plane_id within an access unit may be interleaved with each other under the constraint that for each value of colour_plane_id, the coded slice segment NAL units with that value of colour_plane_id shall be in the order of increasing coding tree block address in tile scan order for the first coding tree block of each coded slice segment NAL unit.

NOTE 2 – When separate_colour_plane_flag is equal to 0, each coding tree block of a picture is contained in exactly one slice. When separate_colour_plane_flag is equal to 1, each coding tree block of a colour component is contained in exactly one slice (i.e. information for each coding tree block of a picture is present in exactly three slices and these three slices have different values of colour_plane_id).

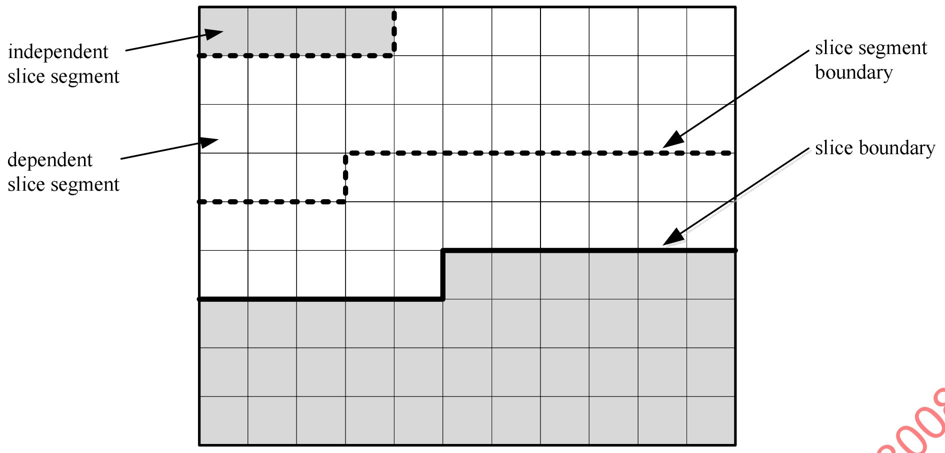


**Figure 6-4 – A picture with 11 by 9 luma coding tree blocks that is partitioned into two slices, the first of which is partitioned into three slice segments (informative)**

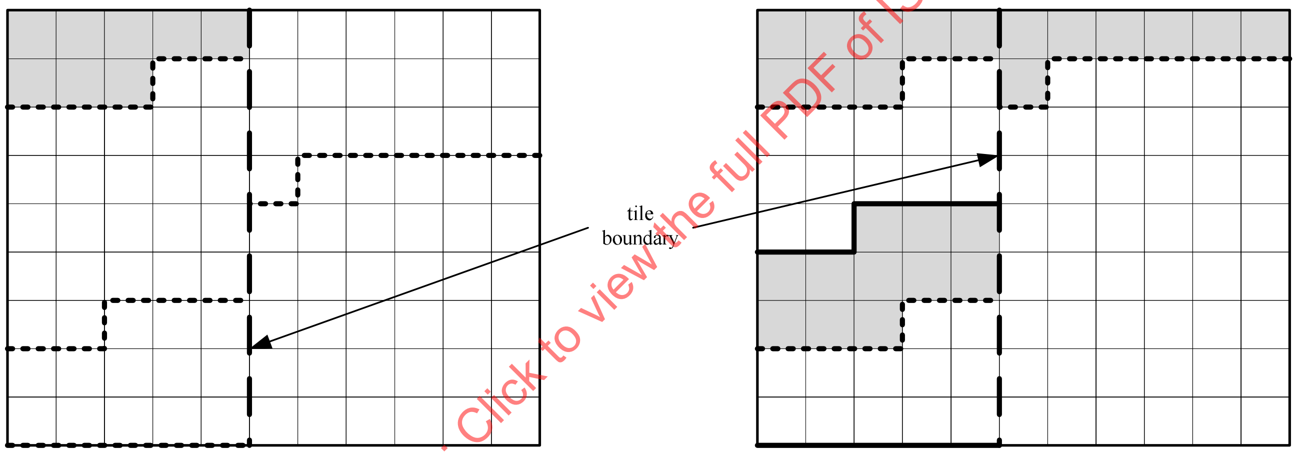


**Figure 6-5 – A picture with 11 by 9 luma coding tree blocks that is partitioned into two tiles and one slice (left) or is partitioned into two tiles and three slices (right) (informative)**

### 6.3.2 Block and quadtree structures

The samples are processed in units of coding tree blocks. The array size for each luma coding tree block in both width and height is CtbSizeY in units of samples. The width and height of the array for each chroma coding tree block are CtbWidthC and CtbHeightC, respectively, in units of samples.

Each coding tree block is assigned a partition signalling to identify the block sizes for intra or inter prediction and for transform coding. The partitioning is a recursive quadtree partitioning. The root of the quadtree is associated with the coding tree block. The quadtree is split until a leaf is reached, which is referred to as the coding block. When the component width is not an integer number of the coding tree block size, the coding tree blocks at the right component boundary are incomplete. When the component height is not an integer multiple of the coding tree block size, the coding tree blocks at the bottom component boundary are incomplete.

The coding block is the root node of two trees, the prediction tree and the transform tree. The prediction tree specifies the position and size of prediction blocks. The transform tree specifies the position and size of transform blocks. The splitting information for luma and chroma is identical for the prediction tree and may or may not be identical for the transform tree.

The blocks and associated syntax structures are encapsulated in a "unit" as follows:

– One prediction block (monochrome picture or separate_colour_plane_flag is equal to 1) or three prediction blocks (luma and chroma) and associated prediction syntax structures units are encapsulated in a prediction unit.

– One transform block (monochrome picture or separate_colour_plane_flag is equal to 1) or three transform blocks (luma and chroma) and associated transform syntax structures units are encapsulated in a transform unit.

– One coding block (monochrome picture or separate_colour_plane_flag is equal to 1) or three coding blocks (luma and chroma), the associated coding syntax structures and the associated prediction and transform units are encapsulated in a coding unit.

– One coding tree block (monochrome picture or separate_colour_plane_flag is equal to 1) or three coding tree blocks (luma and chroma), the associated coding tree syntax structures and the associated coding units are encapsulated in a coding tree unit.

### 6.3.3 Spatial or component-wise partionings

The following divisions of processing elements of this Specification form spatial or component-wise partitionings:

– The division of each picture into components,

– The division of each component into coding tree blocks,

– The division of each picture into tile columns,

– The division of each picture into tile rows,

– The division of each tile column into tiles,

– The division of each tile row into tiles,

– The division of each tile into coding tree units,

– The division of each picture into slices,

– The division of each slice into slice segments,

– The division of each slice segment into coding tree units,

– The division of each coding tree unit into coding tree blocks,

– The division of each coding tree block into coding blocks, except that the coding tree blocks are incomplete at the right component boundary when the component width is not an integer multiple of the coding tree block size and the coding tree blocks are incomplete at the bottom component boundary when the component height is not an integer multiple of the coding tree block size,

– The division of each coding tree unit into coding units, except that the coding tree units are incomplete at the right picture boundary when the picture width in luma samples is not an integer multiple of the luma coding tree block size and the coding tree units are incomplete at the bottom picture boundary when the picture height in luma samples is not an integer multiple of the luma coding tree block size,

– The division of each coding unit into prediction units,

– The division of each coding unit into transform units,

– The division of each coding unit into coding blocks,

– The division of each coding block into prediction blocks,

– The division of each coding block into transform blocks,

– The division of each prediction unit into prediction blocks,

– The division of each transform unit into transform blocks.

## 6.4 Availability processes

### 6.4.1 Derivation process for z-scan order block availability

Inputs to this process are:

– the luma location ( xCurr, yCurr ) of the top-left sample of the current block relative to the top-left luma sample of the current picture,

– the luma location ( xNbY, yNbY ) covered by a neighbouring block relative to the top-left luma sample of the current picture.

Output of this process is the availability of the neighbouring block covering the location ( xNbY, yNbY ), denoted as availableN.

The minimum luma block address in z-scan order minBlockAddrCurr of the current block is derived as follows:

$$\text{minBlockAddrCurr} = \text{MinTbAddrZs}[\ \text{xCurr} >> \text{Log2MinTrafoSize}\ ][\ \text{yCurr} >> \text{Log2MinTrafoSize}\ ] \quad (6\text{-}1)$$

The minimum luma block address in z-scan order minBlockAddrN of the neighbouring block covering the location ( xNbY, yNbY ) is derived as follows:

– If one or more of the following conditions are true, minBlockAddrN is set equal to −1:
  – xNbY is less than 0
  – yNbY is less than 0
  – xNbY is greater than or equal to pic_width_in_luma_samples
  – yNbY is greater than or equal to pic_height_in_luma_samples
– Otherwise (xNbY and yNbY are inside the picture boundaries),

$$\text{minBlockAddrN} = \text{MinTbAddrZs}[\ \text{xNbY} >> \text{Log2MinTrafoSize}\ ][\ \text{yNbY} >> \text{Log2MinTrafoSize}\ ] \quad (6\text{-}2)$$

The neighbouring block availability availableN is derived as follows:

– If one or more of the following conditions are true, availableN is set equal to FALSE:
  – minBlockAddrN is less than 0,
  – minBlockAddrN is greater than minBlockAddrCurr,
  – the variable SliceAddrRs associated with the slice segment containing the neighbouring block with the minimum luma block address minBlockAddrN differs in value from the variable SliceAddrRs associated with the slice segment containing the current block with the minimum luma block address minBlockAddrCurr.
  – the neighbouring block with the minimum luma block address minBlockAddrN is contained in a different tile than the current block with the minimum luma block address minBlockAddrCurr.
– Otherwise, availableN is set equal to TRUE.

### 6.4.2 Derivation process for prediction block availability

Inputs to this process are:

– the luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,
– a variable nCbS specifying the size of the current luma coding block,
– the luma location ( xPb, yPb ) of the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,
– two variables nPbW and nPbH specifying the width and the height of the current luma prediction block,
– a variable partIdx specifying the partition index of the current prediction unit within the current coding unit,
– the luma location ( xNbY, yNbY ) covered by a neighbouring prediction block relative to the top-left luma sample of the current picture.

Output of this process is the availability of the neighbouring prediction block covering the location ( xNbY, yNbY ), denoted as availableN is derived as follows:

The variable sameCb specifying whether the current luma prediction block and the neighbouring luma prediction block cover the same luma coding block.

– If all of the following conditions are true, sameCb is set equal to TRUE:
  – xCb is less than or equal than xNbY,
  – yCb is less than or equal than yNbY,
  – ( xCb + nCbS ) is greater than xNbY,

  – ( yCb + nCbS ) is greater than yNbY.

– Otherwise, sameCb is set equal to FALSE.

The neighbouring prediction block availability availableN is derived as follows:

– If sameCb is equal to FALSE, the derivation process for z-scan order block availability as specified in subclause 6.4.1 is invoked with ( xCurr, yCurr ) set equal to ( xPb, yPb ) and the luma location ( xNbY, yNbY ) as inputs, and the output is assigned to availableN.

– Otherwise, if all of the following conditions are true, availableN is set equal to FALSE:

  – ( nPbW << 1 ) is equal to nCbS,

  – ( nPbH << 1 ) is equal to nCbS,

  – partIdx is equal to 1,

  – ( yCb + nPbH ) is less than or equal to yNbY,

  – ( xCb + nPbW ) is greater than xNbY.

– Otherwise, availableN is set equal to TRUE.

When availableN is equal to TRUE and CuPredMode[ xNbY ][ yNbY ] is equal to MODE_INTRA, availableN is set equal to FALSE.

## 6.5 Scanning processes

### 6.5.1 Coding tree block raster and tile scanning conversion process

The list colWidth[ i ] for i ranging from 0 to num_tile_columns_minus1, inclusive, specifying the width of the i-th tile column in units of CTBs, is derived as follows:

```
if( uniform_spacing_flag )
    for( i = 0; i <= num_tile_columns_minus1; i++ )
        colWidth[ i ] = ( ( i + 1 ) * PicWidthInCtbsY ) / ( num_tile_columns_minus1 + 1 ) −
                    ( i * PicWidthInCtbsY ) / ( num_tile_columns_minus1 + 1 )
else {
    colWidth[ num_tile_columns_minus1 ] = PicWidthInCtbsY                          (6-3)
    for( i = 0; i < num_tile_columns_minus1; i++ ) {
        colWidth[ i ] = column_width_minus1[ i ] + 1
        colWidth[ num_tile_columns_minus1 ] −= colWidth[ i ]
    }
}
```

The list rowHeight[ j ] for j ranging from 0 to num_tile_rows_minus1, inclusive, specifying the height of the j-th tile row in units of CTBs, is derived as follows:

```
if( uniform_spacing_flag )
    for( j = 0; j <= num_tile_rows_minus1; j++ )
        rowHeight[ j ] = ( ( j + 1 ) * PicHeightInCtbsY ) / ( num_tile_rows_minus1 + 1 ) −
                    ( j * PicHeightInCtbsY ) / ( num_tile_rows_minus1 + 1 )
else {
    rowHeight[ num_tile_rows_minus1 ] = PicHeightInCtbsY                          (6-4)
    for( j = 0; j < num_tile_rows_minus1; j++ ) {
        rowHeight[ j ] = row_height_minus1[ j ] + 1
        rowHeight[ num_tile_rows_minus1 ] −= rowHeight[ j ]
    }
}
```

The list colBd[ i ] for i ranging from 0 to num_tile_columns_minus1 + 1, inclusive, specifying the location of the i-th tile column boundary in units of coding tree blocks, is derived as follows:

```
for( colBd[ 0 ] = 0, i = 0; i <= num_tile_columns_minus1; i++ )
    colBd[ i + 1 ] = colBd[ i ] + colWidth[ i ]                                  (6-5)
```

The list rowBd[ j ] for j ranging from 0 to num_tile_rows_minus1 + 1, inclusive, specifying the location of the j-th tile row boundary in units of coding tree blocks, is derived as follows:

```
for( rowBd[ 0 ] = 0, j = 0; j  <=  num_tile_rows_minus1; j++ )
    rowBd[ j + 1 ] = rowBd[ j ] + rowHeight[ j ]                                  (6-6)
```

The list CtbAddrRsToTs[ ctbAddrRs ] for ctbAddrRs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in CTB raster scan of a picture to a CTB address in tile scan, is derived as follows:

```
for( ctbAddrRs = 0; ctbAddrRs < PicSizeInCtbsY; ctbAddrRs++ ) {
    tbX = ctbAddrRs % PicWidthInCtbsY
    tbY = ctbAddrRs / PicWidthInCtbsY
    for( i = 0; i  <=  num_tile_columns_minus1; i++ )
        if( tbX  >=  colBd[ i ] )
            tileX = i
    for( j = 0; j  <=  num_tile_rows_minus1; j++ )                               (6-7)
        if( tbY  >=  rowBd[ j ] )
            tileY = j
    CtbAddrRsToTs[ ctbAddrRs ] = 0
    for( i = 0; i < tileX; i++ )
        CtbAddrRsToTs[ ctbAddrRs ]  +=  rowHeight[ tileY ] * colWidth[ i ]
    for( j = 0; j < tileY; j++ )
        CtbAddrRsToTs[ ctbAddrRs ]  +=  PicWidthInCtbsY * rowHeight[ j ]
    CtbAddrRsToTs[ ctbAddrRs ]  +=  ( tbY − rowBd[ tileY ] ) * colWidth[ tileX ] + tbX − colBd[ tileX ]
}
```

The list CtbAddrTsToRs[ ctbAddrTs ] for ctbAddrTs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in tile scan to a CTB address in CTB raster scan of a picture, is derived as follows:

```
for( ctbAddrRs = 0; ctbAddrRs < PicSizeInCtbsY; ctbAddrRs++ )                    (6-8)
    CtbAddrTsToRs[ CtbAddrRsToTs[ ctbAddrRs ] ] = ctbAddrRs
```

The list TileId[ ctbAddrTs ] for ctbAddrTs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in tile scan to a tile ID, is derived as follows:

```
for( j = 0, tileIdx = 0; j  <=  num_tile_rows_minus1; j++ )
    for( i = 0; i  <=  num_tile_columns_minus1; i++, tileIdx++ )
        for( y = rowBd[ j ]; y < rowBd[ j + 1 ]; y++ )                           (6-9)
            for( x = colBd[ i ]; x < colBd[ i + 1 ]; x++ )
                TileId[ CtbAddrRsToTs[ y * PicWidthInCtbsY+ x ] ] = tileIdx
```

The values of ColumnWidthInLumaSamples[ i ], specifying the width of the i-th tile column in units of luma samples, are set equal to colWidth[ i ]  <<  CtbLog2SizeY for i ranging from 0 to num_tile_columns_minus1, inclusive.

The values of RowHeightInLumaSamples[ j ], specifying the height of the j-th tile row in units of luma samples, are set equal to rowHeight[ j ]  <<  CtbLog2SizeY for j ranging from 0 to num_tile_rows_minus1, inclusive.

### 6.5.2 Z-scan order array initialization process

The array MinTbAddrZs with elements MinTbAddrZs[ x ][ y ] for x ranging from 0 to ( PicWidthInCtbsY  <<  ( CtbLog2SizeY − Log2MinTrafoSize ) ) − 1, inclusive, and y ranging from 0 to ( PicHeightInCtbsY  <<  ( CtbLog2SizeY − Log2MinTrafoSize ) ) − 1, specifying the conversion from a location ( x, y ) in units of minimum blocks to a minimum block address in z-scan order, inclusive is derived as follows:

```
for( y = 0; y < ( PicHeightInCtbsY  <<  ( CtbLog2SizeY − Log2MinTrafoSize ) ); y++ )
    for( x = 0; x < ( PicWidthInCtbsY  <<  ( CtbLog2SizeY − Log2MinTrafoSize ) ); x++) {
        tbX = ( x  <<  Log2MinTrafoSize )  >>  CtbLog2SizeY
        tbY = ( y  <<  Log2MinTrafoSize )  >>  CtbLog2SizeY
        ctbAddrRs = PicWidthInCtbsY * tbY + tbX
        MinTbAddrZs[ x ][ y ] = CtbAddrRsToTs[ ctbAddrRs ]  <<                   (6-10)
                ( ( CtbLog2SizeY − Log2MinTrafoSize ) * 2 )
        for( i = 0, p = 0; i < ( CtbLog2SizeY − Log2MinTrafoSize ); i++ ) {
            m = 1  <<  i
            p  +=  ( m & x ? m * m : 0 ) + ( m & y ? 2 * m * m : 0 )
        }
        MinTbAddrZs[ x ][ y ]  +=  p
    }
```

### 6.5.3 Up-right diagonal scan order array initialization process

Input to this process is a block size blkSize.

Output of this process is the array diagScan[ sPos ][ sComp ]. The array index sPos specify the scan position ranging from 0 to ( blkSize * blkSize ) − 1. The array index sComp equal to 0 specifies the horizontal component and the array index sComp equal to 1 specifies the vertical component. Depending on the value of blkSize, the array diagScan is derived as follows:

```
i = 0
x = 0
y = 0
stopLoop = FALSE
while( !stopLoop ) {
    while( y >= 0 ) {
        if( x < blkSize && y < blkSize ) {                                  (6-11)
            diagScan[ i ][ 0 ] = x
            diagScan[ i ][ 1 ] = y
            i++
        }
        y− −
        x++
    }
    y = x
    x = 0
    if( i >= blkSize * blkSize )
        stopLoop = TRUE
}
```

### 6.5.4 Horizontal scan order array initialization process

Input to this process is a block size blkSize.

Output of this process is the array horScan[ sPos ][ sComp ]. The array index sPos specifies the scan position ranging from 0 to ( blkSize * blkSize ) − 1. The array index sComp equal to 0 specifies the horizontal component and the array index sComp equal to 1 specifies the vertical component. Depending on the value of blkSize, the array horScan is derived as follows:

```
i = 0
for( y = 0; y < blkSize; y++ )
    for( x = 0; x < blkSize; x++ ) {
        horScan[ i ][ 0 ] = x                                               (6-12)
        horScan[ i ][ 1 ] = y
        i++
    }
```

### 6.5.5 Vertical scan order array initialization process

Input to this process is a block size blkSize.

Output of this process is the array verScan[ sPos ][ sComp ]. The array index sPos specifies the scan position ranging from 0 to ( blkSize * blkSize ) − 1. The array index sComp equal to 0 specifies the horizontal component and the array index sComp equal to 1 specifies the vertical component. Depending on the value of blkSize, the array verScan is derived as follows:

```
i = 0
for( x = 0; x < blkSize; x++ )
    for( y = 0; y < blkSize; y++ ) {
        verScan[ i ][ 0 ] = x                                               (6-13)
        verScan[ i ][ 1 ] = y
        i++
    }
```

## 7 Syntax and semantics

### 7.1 Method of specifying syntax in tabular form

The syntax tables specify a superset of the syntax of all allowed bitstreams. Additional constraints on the syntax may be specified, either directly or indirectly, in other clauses.

NOTE – An actual decoder should implement some means for identifying entry points into the bitstream and some means to identify and handle non-conforming bitstreams. The methods for identifying and handling errors and other such situations are not specified in this Specification.

The following table lists examples of the syntax specification format. When **syntax_element** appears, it specifies that a syntax element is parsed from the bitstream and the bitstream pointer is advanced to the next position beyond the syntax element in the bitstream 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 | |

## 7.2 Specification of syntax functions and descriptors

The functions presented here are used in the syntactical description. These functions are expressed in terms of the value of a bitstream pointer that indicates the position of the next bit to be read by the decoding process from the bitstream.

byte_aligned( ) is specified as follows:

– If the current position in the bitstream is on a byte boundary, i.e. the next bit in the bitstream is the first bit in a byte, the return value of byte_aligned( ) is equal to TRUE.

– Otherwise, the return value of byte_aligned( ) is equal to FALSE.

more_data_in_byte_stream( ), which is used only in the byte stream NAL unit syntax structure specified in Annex B, is specified as follows:

– If more data follow in the byte stream, the return value of more_data_in_byte_stream( ) is equal to TRUE.

– Otherwise, the return value of more_data_in_byte_stream( ) is equal to FALSE.

more_data_in_payload( ) is specified as follows:

– If byte_aligned( ) is equal to TRUE and the current position in the sei_payload( ) syntax structure is 8 * payloadSize bits from the beginning of the sei_payload( ) syntax structure, the return value of more_data_in_payload( ) is equal to FALSE.

– Otherwise, the return value of more_data_in_payload( ) is equal to TRUE.

more_rbsp_data( ) is specified as follows:

– If there is no more data in the RBSP, the return value of more_rbsp_data( ) is equal to FALSE.

– Otherwise, the RBSP data are searched for the last (least significant, right-most) bit equal to 1 that is present in the RBSP. Given the position of this bit, which is the first bit (rbsp_stop_one_bit) of the rbsp_trailing_bits( ) syntax structure, the following applies:

  – If there is more data in an RBSP before the rbsp_trailing_bits( ) syntax structure, the return value of more_rbsp_data( ) is equal to TRUE.

  – Otherwise, the return value of more_rbsp_data( ) is equal to FALSE.

The method for enabling determination of whether there is more data in the RBSP is specified by the application (or in Annex B for applications that use the byte stream format).

more_rbsp_trailing_data( ) is specified as follows:

– If there is more data in an RBSP, the return value of more_rbsp_trailing_data( ) is equal to TRUE.

– Otherwise, the return value of more_rbsp_trailing_data( ) is equal to FALSE.

payload_extension_present( ) is specified as follows:

– If the current position in the sei_payload( ) syntax structure is not the position of the last (least significant, right-most) bit that is equal to 1 that is less than 8 * payloadSize bits from the beginning of the syntax structure (i.e. the position of the bit_equal_to_one syntax element), the return value of payload_extension_present( ) is equal to TRUE.

– Otherwise, the return value of payload_extension_present( ) is equal to FALSE.

next_bits( n ) provides the next bits in the bitstream for comparison purposes, without advancing the bitstream pointer. Provides a look at the next n bits in the bitstream with n being its argument. When used within the byte stream format as specified in Annex B and fewer than n bits remain within the byte stream, next_bits( n ) returns a value of 0.

read_bits( n ) reads the next n bits from the bitstream and advances the bitstream 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 bitstream pointer.

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

– ae(v): context-adaptive arithmetic entropy-coded syntax element. The parsing process for this descriptor is specified in subclause 9.3.

– 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 ).

– 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 subclause 9.2.

– 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 subclause 9.2.

## 7.3 Syntax in tabular form

### 7.3.1 NAL unit syntax

#### 7.3.1.1 General NAL unit syntax

| nal_unit( NumBytesInNalUnit ) { | **Descriptor** |
|---|---|
|   nal_unit_header( ) | |
|   NumBytesInRbsp = 0 | |
|   for( i = 2; i < NumBytesInNalUnit; i++ ) | |
|     if( i + 2 < NumBytesInNalUnit && next_bits( 24 ) = = 0x000003 ) { | |
|       **rbsp_byte**[ NumBytesInRbsp++ ] | b(8) |
|       **rbsp_byte**[ NumBytesInRbsp++ ] | b(8) |
|       i += 2 | |
|       **emulation_prevention_three_byte** /* equal to 0x03 */ | f(8) |
|     } else | |
|       **rbsp_byte**[ NumBytesInRbsp++ ] | b(8) |
| } | |

#### 7.3.1.2 NAL unit header syntax

| nal_unit_header( ) { | **Descriptor** |
|---|---|
|   **forbidden_zero_bit** | f(1) |
|   **nal_unit_type** | u(6) |
|   **nuh_layer_id** | u(6) |
|   **nuh_temporal_id_plus1** | u(3) |
| } | |

### 7.3.2 Raw byte sequence payloads, trailing bits, and byte alignment syntax

#### 7.3.2.1 Video parameter set RBSP syntax

| video_parameter_set_rbsp( ) { | **Descriptor** |
|---|---|
|   **vps_video_parameter_set_id** | u(4) |
|   **vps_reserved_three_2bits** | u(2) |
|   **vps_max_layers_minus1** | u(6) |
|   **vps_max_sub_layers_minus1** | u(3) |
|   **vps_temporal_id_nesting_flag** | u(1) |
|   **vps_reserved_0xffff_16bits** | u(16) |
|   profile_tier_level( vps_max_sub_layers_minus1 ) | |
|   **vps_sub_layer_ordering_info_present_flag** | u(1) |
|   for( i = ( vps_sub_layer_ordering_info_present_flag ? 0 : vps_max_sub_layers_minus1 ); i <= vps_max_sub_layers_minus1; i++ ) { | |
|     **vps_max_dec_pic_buffering_minus1**[ i ] | ue(v) |
|     **vps_max_num_reorder_pics**[ i ] | ue(v) |
|     **vps_max_latency_increase_plus1**[ i ] | ue(v) |
|   } | |
|   **vps_max_layer_id** | u(6) |
|   **vps_num_layer_sets_minus1** | ue(v) |
|   for( i = 1; i <= vps_num_layer_sets_minus1; i++ ) | |
|     for( j = 0; j <= vps_max_layer_id; j++ ) | |
|       **layer_id_included_flag**[ i ][ j ] | u(1) |
|   **vps_timing_info_present_flag** | u(1) |
|   if( vps_timing_info_present_flag ) { | |
|     **vps_num_units_in_tick** | u(32) |
|     **vps_time_scale** | u(32) |
|     **vps_poc_proportional_to_timing_flag** | u(1) |
|     if( vps_poc_proportional_to_timing_flag ) | |
|       **vps_num_ticks_poc_diff_one_minus1** | ue(v) |
|     **vps_num_hrd_parameters** | ue(v) |
|     for( i = 0; i < vps_num_hrd_parameters; i++ ) { | |
|       **hrd_layer_set_idx**[ i ] | ue(v) |
|       if( i > 0 ) | |
|         **cprms_present_flag**[ i ] | u(1) |
|       hrd_parameters( cprms_present_flag[ i ], vps_max_sub_layers_minus1 ) | |
|     } | |
|   } | |
|   **vps_extension_flag** | u(1) |
|   if( vps_extension_flag ) | |
|     while( more_rbsp_data( ) ) | |
|       **vps_extension_data_flag** | u(1) |
|   rbsp_trailing_bits( ) | |
| } | |

### 7.3.2.2 Sequence parameter set RBSP syntax

| seq_parameter_set_rbsp( ) { | **Descriptor** |
|---|---|
| **sps_video_parameter_set_id** | u(4) |
| **sps_max_sub_layers_minus1** | u(3) |
| **sps_temporal_id_nesting_flag** | u(1) |
| profile_tier_level( sps_max_sub_layers_minus1 ) | |
| **sps_seq_parameter_set_id** | ue(v) |
| **chroma_format_idc** | ue(v) |
| if( chroma_format_idc = = 3 ) | |
| **separate_colour_plane_flag** | u(1) |
| **pic_width_in_luma_samples** | ue(v) |
| **pic_height_in_luma_samples** | ue(v) |
| **conformance_window_flag** | u(1) |
| if( conformance_window_flag ) { | |
| **conf_win_left_offset** | ue(v) |
| **conf_win_right_offset** | ue(v) |
| **conf_win_top_offset** | ue(v) |
| **conf_win_bottom_offset** | ue(v) |
| } | |
| **bit_depth_luma_minus8** | ue(v) |
| **bit_depth_chroma_minus8** | ue(v) |
| **log2_max_pic_order_cnt_lsb_minus4** | ue(v) |
| **sps_sub_layer_ordering_info_present_flag** | u(1) |
| for( i = ( sps_sub_layer_ordering_info_present_flag ? 0 : sps_max_sub_layers_minus1 ); i <= sps_max_sub_layers_minus1; i++ ) { | |
| **sps_max_dec_pic_buffering_minus1**[ i ] | ue(v) |
| **sps_max_num_reorder_pics**[ i ] | ue(v) |
| **sps_max_latency_increase_plus1**[ i ] | ue(v) |
| } | |
| **log2_min_luma_coding_block_size_minus3** | ue(v) |
| **log2_diff_max_min_luma_coding_block_size** | ue(v) |
| **log2_min_transform_block_size_minus2** | ue(v) |
| **log2_diff_max_min_transform_block_size** | ue(v) |
| **max_transform_hierarchy_depth_inter** | ue(v) |
| **max_transform_hierarchy_depth_intra** | ue(v) |
| **scaling_list_enabled_flag** | u(1) |
| if( scaling_list_enabled_flag ) { | |
| **sps_scaling_list_data_present_flag** | u(1) |
| if( sps_scaling_list_data_present_flag ) | |
| scaling_list_data( ) | |
| } | |
| **amp_enabled_flag** | u(1) |
| **sample_adaptive_offset_enabled_flag** | u(1) |
| **pcm_enabled_flag** | u(1) |
| if( pcm_enabled_flag ) { | |
| **pcm_sample_bit_depth_luma_minus1** | u(4) |
| **pcm_sample_bit_depth_chroma_minus1** | u(4) |
| **log2_min_pcm_luma_coding_block_size_minus3** | ue(v) |

| | |
|---|---|
|         **log2_diff_max_min_pcm_luma_coding_block_size** | ue(v) |
|         **pcm_loop_filter_disabled_flag** | u(1) |
|     } | |
|     **num_short_term_ref_pic_sets** | ue(v) |
|     for( i = 0; i < num_short_term_ref_pic_sets; i++) | |
|         short_term_ref_pic_set( i ) | |
|     **long_term_ref_pics_present_flag** | u(1) |
|     if( long_term_ref_pics_present_flag ) { | |
|         **num_long_term_ref_pics_sps** | ue(v) |
|         for( i = 0; i < num_long_term_ref_pics_sps; i++ ) { | |
|             **lt_ref_pic_poc_lsb_sps**[ i ] | u(v) |
|             **used_by_curr_pic_lt_sps_flag**[ i ] | u(1) |
|         } | |
|     } | |
|     **sps_temporal_mvp_enabled_flag** | u(1) |
|     **strong_intra_smoothing_enabled_flag** | u(1) |
|     **vui_parameters_present_flag** | u(1) |
|     if( vui_parameters_present_flag ) | |
|         vui_parameters( ) | |
|     **sps_extension_flag** | u(1) |
|     if( sps_extension_flag ) | |
|         while( more_rbsp_data( ) ) | |
|             **sps_extension_data_flag** | u(1) |
|     rbsp_trailing_bits( ) | |
| } | |

### 7.3.2.3 Picture parameter set RBSP syntax

| pic_parameter_set_rbsp( ) { | **Descriptor** |
|---|---|
|   **pps_pic_parameter_set_id** | ue(v) |
|   **pps_seq_parameter_set_id** | ue(v) |
|   **dependent_slice_segments_enabled_flag** | u(1) |
|   **output_flag_present_flag** | u(1) |
|   **num_extra_slice_header_bits** | u(3) |
|   **sign_data_hiding_enabled_flag** | u(1) |
|   **cabac_init_present_flag** | u(1) |
|   **num_ref_idx_l0_default_active_minus1** | ue(v) |
|   **num_ref_idx_l1_default_active_minus1** | ue(v) |
|   **init_qp_minus26** | se(v) |
|   **constrained_intra_pred_flag** | u(1) |
|   **transform_skip_enabled_flag** | u(1) |
|   **cu_qp_delta_enabled_flag** | u(1) |
|   if( cu_qp_delta_enabled_flag ) | |
|     **diff_cu_qp_delta_depth** | ue(v) |
|   **pps_cb_qp_offset** | se(v) |
|   **pps_cr_qp_offset** | se(v) |
|   **pps_slice_chroma_qp_offsets_present_flag** | u(1) |
|   **weighted_pred_flag** | u(1) |
|   **weighted_bipred_flag** | u(1) |
|   **transquant_bypass_enabled_flag** | u(1) |
|   **tiles_enabled_flag** | u(1) |
|   **entropy_coding_sync_enabled_flag** | u(1) |
|   if( tiles_enabled_flag ) { | |
|     **num_tile_columns_minus1** | ue(v) |
|     **num_tile_rows_minus1** | ue(v) |
|     **uniform_spacing_flag** | u(1) |
|     if( !uniform_spacing_flag ) { | |
|       for( i = 0; i < num_tile_columns_minus1; i++ ) | |
|         **column_width_minus1**[ i ] | ue(v) |
|       for( i = 0; i < num_tile_rows_minus1; i++ ) | |
|         **row_height_minus1**[ i ] | ue(v) |
|     } | |
|     **loop_filter_across_tiles_enabled_flag** | u(1) |
|   } | |
|   **pps_loop_filter_across_slices_enabled_flag** | u(1) |
|   **deblocking_filter_control_present_flag** | u(1) |
|   if( deblocking_filter_control_present_flag ) { | |
|     **deblocking_filter_override_enabled_flag** | u(1) |
|     **pps_deblocking_filter_disabled_flag** | u(1) |
|     if( !pps_deblocking_filter_disabled_flag ) { | |
|       **pps_beta_offset_div2** | se(v) |
|       **pps_tc_offset_div2** | se(v) |
|     } | |
|   } | |

| | |
|---|---|
| **pps_scaling_list_data_present_flag** | u(1) |
| if( pps_scaling_list_data_present_flag ) | |
| scaling_list_data( ) | |
| **lists_modification_present_flag** | u(1) |
| **log2_parallel_merge_level_minus2** | ue(v) |
| **slice_segment_header_extension_present_flag** | u(1) |
| **pps_extension_flag** | u(1) |
| if( pps_extension_flag ) | |
| while( more_rbsp_data( ) ) | |
| **pps_extension_data_flag** | u(1) |
| rbsp_trailing_bits( ) | |
| } | |

### 7.3.2.4 Supplemental enhancement information RBSP syntax

| sei_rbsp( ) { | **Descriptor** |
|---|---|
| do | |
| sei_message( ) | |
| while( more_rbsp_data( ) ) | |
| rbsp_trailing_bits( ) | |
| } | |

### 7.3.2.5 Access unit delimiter RBSP syntax

| access_unit_delimiter_rbsp( ) { | **Descriptor** |
|---|---|
| **pic_type** | u(3) |
| rbsp_trailing_bits( ) | |
| } | |

### 7.3.2.6 End of sequence RBSP syntax

| end_of_seq_rbsp( ) { | **Descriptor** |
|---|---|
| } | |

### 7.3.2.7 End of bitstream RBSP syntax

| end_of_bitstream_rbsp( ) { | **Descriptor** |
|---|---|
| } | |

#### 7.3.2.8 Filler data RBSP syntax

| filler_data_rbsp( ) { | **Descriptor** |
|---|---|
|   while( next_bits( 8 ) = = 0xFF ) | |
|     **ff_byte** /* equal to 0xFF */ | f(8) |
|   rbsp_trailing_bits( ) | |
| } | |

#### 7.3.2.9 Slice segment layer RBSP syntax

| slice_segment_layer_rbsp( ) { | **Descriptor** |
|---|---|
|   slice_segment_header( ) | |
|   slice_segment_data( ) | |
|   rbsp_slice_segment_trailing_bits( ) | |
| } | |

#### 7.3.2.10 RBSP slice segment trailing bits syntax

| rbsp_slice_segment_trailing_bits( ) { | **Descriptor** |
|---|---|
|   rbsp_trailing_bits( ) | |
|   while( more_rbsp_trailing_data( ) ) | |
|     **cabac_zero_word** /* equal to 0x0000 */ | f(16) |
| } | |

#### 7.3.2.11 RBSP trailing bits syntax

| rbsp_trailing_bits( ) { | **Descriptor** |
|---|---|
|   **rbsp_stop_one_bit** /* equal to 1 */ | f(1) |
|   while( !byte_aligned( ) ) | |
|     **rbsp_alignment_zero_bit** /* equal to 0 */ | f(1) |
| } | |

#### 7.3.2.12 Byte alignment syntax

| byte_alignment( ) { | **Descriptor** |
|---|---|
|   **alignment_bit_equal_to_one** /* equal to 1 */ | f(1) |
|   while( !byte_aligned( ) ) | |
|     **alignment_bit_equal_to_zero** /* equal to 0 */ | f(1) |
| } | |

### 7.3.3 Profile, tier and level syntax

| profile_tier_level( maxNumSubLayersMinus1 ) { | **Descriptor** |
|---|---|
|   **general_profile_space** | u(2) |
|   **general_tier_flag** | u(1) |
|   **general_profile_idc** | u(5) |
|   for( j = 0; j < 32; j++ ) | |
|     **general_profile_compatibility_flag**[ j ] | u(1) |
|   **general_progressive_source_flag** | u(1) |
|   **general_interlaced_source_flag** | u(1) |
|   **general_non_packed_constraint_flag** | u(1) |
|   **general_frame_only_constraint_flag** | u(1) |
|   **general_reserved_zero_44bits** | u(44) |
|   **general_level_idc** | u(8) |
|   for( i = 0; i < maxNumSubLayersMinus1; i++ ) { | |
|     **sub_layer_profile_present_flag**[ i ] | u(1) |
|     **sub_layer_level_present_flag**[ i ] | u(1) |
|   } | |
|   if( maxNumSubLayersMinus1 > 0 ) | |
|     for( i = maxNumSubLayersMinus1; i < 8; i++ ) | |
|       **reserved_zero_2bits**[ i ] | u(2) |
|   for( i = 0; i < maxNumSubLayersMinus1; i++ ) { | |
|     if( sub_layer_profile_present_flag[ i ] ) { | |
|       **sub_layer_profile_space**[ i ] | u(2) |
|       **sub_layer_tier_flag**[ i ] | u(1) |
|       **sub_layer_profile_idc**[ i ] | u(5) |
|       for( j = 0; j < 32; j++ ) | |
|         **sub_layer_profile_compatibility_flag**[ i ][ j ] | u(1) |
|       **sub_layer_progressive_source_flag**[ i ] | u(1) |
|       **sub_layer_interlaced_source_flag**[ i ] | u(1) |
|       **sub_layer_non_packed_constraint_flag**[ i ] | u(1) |
|       **sub_layer_frame_only_constraint_flag**[ i ] | u(1) |
|       **sub_layer_reserved_zero_44bits**[ i ] | u(44) |
|     } | |
|     if( sub_layer_level_present_flag[ i ] ) | |
|       **sub_layer_level_idc**[ i ] | u(8) |
|   } | |
| } | |

### 7.3.4 Scaling list data syntax

| scaling_list_data( ) { | **Descriptor** |
|---|---|
|   for( sizeId = 0; sizeId < 4; sizeId++ ) | |
|     for( matrixId = 0; matrixId < ( ( sizeId  = =  3 ) ? 2 : 6 ); matrixId++ ) { | |
|       **scaling_list_pred_mode_flag**[ sizeId ][ matrixId ] | u(1) |
|       if( !scaling_list_pred_mode_flag[ sizeId ][ matrixId ] ) | |
|         **scaling_list_pred_matrix_id_delta**[ sizeId ][ matrixId ] | ue(v) |
|       else { | |
|         nextCoef = 8 | |
|         coefNum = Min( 64, ( 1  <<  ( 4 + ( sizeId  <<  1 ) ) ) ) | |
|         if( sizeId > 1 ) { | |
|           **scaling_list_dc_coef_minus8**[ sizeId − 2 ][ matrixId ] | se(v) |
|           nextCoef = scaling_list_dc_coef_minus8[ sizeId − 2 ][ matrixId ] + 8 | |
|         } | |
|         for( i = 0; i < coefNum; i++) { | |
|           **scaling_list_delta_coef** | se(v) |
|           nextCoef = ( nextCoef + scaling_list_delta_coef + 256 ) % 256 | |
|           ScalingList[ sizeId ][ matrixId ][ i ] = nextCoef | |
|         } | |
|       } | |
|     } | |
| } | |

### 7.3.5 Supplemental enhancement information message syntax

| sei_message( ) { | **Descriptor** |
|---|---|
|   payloadType = 0 | |
|   while( next_bits( 8 )  = =  0xFF ) { | |
|     **ff_byte**  /* equal to 0xFF */ | f(8) |
|     payloadType  +=  255 | |
|   } | |
|   **last_payload_type_byte** | u(8) |
|   payloadType  +=  last_payload_type_byte | |
|   payloadSize = 0 | |
|   while( next_bits( 8 )  = =  0xFF ) { | |
|     **ff_byte**  /* equal to 0xFF */ | f(8) |
|     payloadSize  +=  255 | |
|   } | |
|   **last_payload_size_byte** | u(8) |
|   payloadSize  +=  last_payload_size_byte | |
|   sei_payload( payloadType, payloadSize ) | |
| } | |

### 7.3.6 Slice segment header syntax

#### 7.3.6.1 General slice segment header syntax

| slice_segment_header( ) { | **Descriptor** |
|---|---|
|     **first_slice_segment_in_pic_flag** | u(1) |
|     if( nal_unit_type >= BLA_W_LP && nal_unit_type <= RSV_IRAP_VCL23 ) | |
|         **no_output_of_prior_pics_flag** | u(1) |
|     **slice_pic_parameter_set_id** | ue(v) |
|     if( !first_slice_segment_in_pic_flag ) { | |
|         if( dependent_slice_segments_enabled_flag ) | |
|             **dependent_slice_segment_flag** | u(1) |
|         **slice_segment_address** | u(v) |
|     } | |
|     if( !dependent_slice_segment_flag ) { | |
|         for( i = 0; i < num_extra_slice_header_bits; i++ ) | |
|             **slice_reserved_flag**[ i ] | u(1) |
|         **slice_type** | ue(v) |
|         if( output_flag_present_flag ) | |
|             **pic_output_flag** | u(1) |
|         if( separate_colour_plane_flag = = 1 ) | |
|             **colour_plane_id** | u(2) |
|         if( nal_unit_type != IDR_W_RADL && nal_unit_type != IDR_N_LP ) { | |
|             **slice_pic_order_cnt_lsb** | u(v) |
|             **short_term_ref_pic_set_sps_flag** | u(1) |
|             if( !short_term_ref_pic_set_sps_flag ) | |
|                 short_term_ref_pic_set( num_short_term_ref_pic_sets ) | |
|             else if( num_short_term_ref_pic_sets > 1 ) | |
|                 **short_term_ref_pic_set_idx** | u(v) |
|             if( long_term_ref_pics_present_flag ) { | |
|                 if( num_long_term_ref_pics_sps > 0 ) | |
|                     **num_long_term_sps** | ue(v) |
|                 **num_long_term_pics** | ue(v) |
|                 for( i = 0; i < num_long_term_sps + num_long_term_pics; i++ ) { | |
|                     if( i < num_long_term_sps ) { | |
|                         if( num_long_term_ref_pics_sps > 1 ) | |
|                             **lt_idx_sps**[ i ] | u(v) |
|                     } else { | |
|                         **poc_lsb_lt**[ i ] | u(v) |
|                         **used_by_curr_pic_lt_flag**[ i ] | u(1) |
|                     } | |
|                     **delta_poc_msb_present_flag**[ i ] | u(1) |
|                     if( delta_poc_msb_present_flag[ i ] ) | |
|                         **delta_poc_msb_cycle_lt**[ i ] | ue(v) |
|                 } | |
|             } | |
|             if( sps_temporal_mvp_enabled_flag ) | |
|                 **slice_temporal_mvp_enabled_flag** | u(1) |
|         } | |

| | |
|---|---|
| if( sample_adaptive_offset_enabled_flag ) { | |
| **slice_sao_luma_flag** | u(1) |
| **slice_sao_chroma_flag** | u(1) |
| } | |
| if( slice_type = = P \|\| slice_type = = B ) { | |
| **num_ref_idx_active_override_flag** | u(1) |
| if( num_ref_idx_active_override_flag ) { | |
| **num_ref_idx_l0_active_minus1** | ue(v) |
| if( slice_type = = B ) | |
| **num_ref_idx_l1_active_minus1** | ue(v) |
| } | |
| if( lists_modification_present_flag && NumPocTotalCurr > 1 ) | |
| ref_pic_lists_modification( ) | |
| if( slice_type = = B ) | |
| **mvd_l1_zero_flag** | u(1) |
| if( cabac_init_present_flag ) | |
| **cabac_init_flag** | u(1) |
| if( slice_temporal_mvp_enabled_flag ) { | |
| if( slice_type = = B ) | |
| **collocated_from_l0_flag** | u(1) |
| if( ( collocated_from_l0_flag && num_ref_idx_l0_active_minus1 > 0 ) \|\|<br>( !collocated_from_l0_flag && num_ref_idx_l1_active_minus1 > 0 ) ) | |
| **collocated_ref_idx** | ue(v) |
| } | |
| if( ( weighted_pred_flag && slice_type = = P ) \|\|<br>( weighted_bipred_flag && slice_type = = B ) ) | |
| pred_weight_table( ) | |
| **five_minus_max_num_merge_cand** | ue(v) |
| } | |
| **slice_qp_delta** | se(v) |
| if( pps_slice_chroma_qp_offsets_present_flag ) { | |
| **slice_cb_qp_offset** | se(v) |
| **slice_cr_qp_offset** | se(v) |
| } | |
| if( deblocking_filter_override_enabled_flag ) | |
| **deblocking_filter_override_flag** | u(1) |
| if( deblocking_filter_override_flag ) { | |
| **slice_deblocking_filter_disabled_flag** | u(1) |
| if( !slice_deblocking_filter_disabled_flag ) { | |
| **slice_beta_offset_div2** | se(v) |
| **slice_tc_offset_div2** | se(v) |
| } | |
| } | |
| if( pps_loop_filter_across_slices_enabled_flag &&<br>( slice_sao_luma_flag \|\| slice_sao_chroma_flag \|\|<br>!slice_deblocking_filter_disabled_flag ) ) | |
| **slice_loop_filter_across_slices_enabled_flag** | u(1) |
| } | |
| if( tiles_enabled_flag \|\| entropy_coding_sync_enabled_flag ) { | |
| **num_entry_point_offsets** | ue(v) |

| | |
|---|---|
| if( num_entry_point_offsets > 0 ) { | |
| **offset_len_minus1** | ue(v) |
| for( i = 0; i < num_entry_point_offsets; i++ ) | |
| **entry_point_offset_minus1**[ i ] | u(v) |
| } | |
| } | |
| if( slice_segment_header_extension_present_flag ) { | |
| **slice_segment_header_extension_length** | ue(v) |
| for( i = 0; i < slice_segment_header_extension_length; i++) | |
| **slice_segment_header_extension_data_byte**[ i ] | u(8) |
| } | |
| byte_alignment( ) | |
| } | |

### 7.3.6.2 Reference picture list modification syntax

| ref_pic_lists_modification( ) { | **Descriptor** |
|---|---|
| **ref_pic_list_modification_flag_l0** | u(1) |
| if( ref_pic_list_modification_flag_l0 ) | |
| for( i = 0; i <= num_ref_idx_l0_active_minus1; i++ ) | |
| **list_entry_l0**[ i ] | u(v) |
| if( slice_type = = B ) { | |
| **ref_pic_list_modification_flag_l1** | u(1) |
| if( ref_pic_list_modification_flag_l1 ) | |
| for( i = 0; i <= num_ref_idx_l1_active_minus1; i++ ) | |
| **list_entry_l1**[ i ] | u(v) |
| } | |
| } | |

### 7.3.6.3 Weighted prediction parameters syntax

| pred_weight_table( ) { | **Descriptor** |
|---|---|
|   **luma_log2_weight_denom** | ue(v) |
|   if( chroma_format_idc != 0 ) | |
|     **delta_chroma_log2_weight_denom** | se(v) |
|   for( i = 0; i <= num_ref_idx_l0_active_minus1; i++ ) | |
|     **luma_weight_l0_flag**[ i ] | u(1) |
|   if( chroma_format_idc != 0 ) | |
|     for( i = 0; i <= num_ref_idx_l0_active_minus1; i++ ) | |
|       **chroma_weight_l0_flag**[ i ] | u(1) |
|   for( i = 0; i <= num_ref_idx_l0_active_minus1; i++ ) { | |
|     if( luma_weight_l0_flag[ i ] ) { | |
|       **delta_luma_weight_l0**[ i ] | se(v) |
|       **luma_offset_l0**[ i ] | se(v) |
|     } | |
|     if( chroma_weight_l0_flag[ i ] ) | |
|       for( j = 0; j < 2; j++ ) { | |
|         **delta_chroma_weight_l0**[ i ][ j ] | se(v) |
|         **delta_chroma_offset_l0**[ i ][ j ] | se(v) |
|       } | |
|   } | |
|   if( slice_type = = B ) { | |
|     for( i = 0; i <= num_ref_idx_l1_active_minus1; i++ ) | |
|       **luma_weight_l1_flag**[ i ] | u(1) |
|     if( chroma_format_idc != 0 ) | |
|       for( i = 0; i <= num_ref_idx_l1_active_minus1; i++ ) | |
|         **chroma_weight_l1_flag**[ i ] | u(1) |
|     for( i = 0; i <= num_ref_idx_l1_active_minus1; i++ ) { | |
|       if( luma_weight_l1_flag[ i ] ) { | |
|         **delta_luma_weight_l1**[ i ] | se(v) |
|         **luma_offset_l1**[ i ] | se(v) |
|       } | |
|       if( chroma_weight_l1_flag[ i ] ) | |
|         for( j = 0; j < 2; j++ ) { | |
|           **delta_chroma_weight_l1**[ i ][ j ] | se(v) |
|           **delta_chroma_offset_l1**[ i ][ j ] | se(v) |
|         } | |
|     } | |
|   } | |
| } | |

### 7.3.7 Short-term reference picture set syntax

| short_term_ref_pic_set( stRpsIdx ) { | **Descriptor** |
|---|---|
|  if( stRpsIdx != 0 ) | |
|   **inter_ref_pic_set_prediction_flag** | u(1) |
|  if( inter_ref_pic_set_prediction_flag ) { | |
|   if( stRpsIdx = = num_short_term_ref_pic_sets ) | |
|    **delta_idx_minus1** | ue(v) |
|   **delta_rps_sign** | u(1) |
|   **abs_delta_rps_minus1** | ue(v) |
|   for( j = 0; j <= NumDeltaPocs[ RefRpsIdx ]; j++ ) { | |
|    **used_by_curr_pic_flag**[ j ] | u(1) |
|    if( !used_by_curr_pic_flag[ j ] ) | |
|     **use_delta_flag**[ j ] | u(1) |
|   } | |
|  } else { | |
|   **num_negative_pics** | ue(v) |
|   **num_positive_pics** | ue(v) |
|   for( i = 0; i < num_negative_pics; i++ ) { | |
|    **delta_poc_s0_minus1**[ i ] | ue(v) |
|    **used_by_curr_pic_s0_flag**[ i ] | u(1) |
|   } | |
|   for( i = 0; i < num_positive_pics; i++ ) { | |
|    **delta_poc_s1_minus1**[ i ] | ue(v) |
|    **used_by_curr_pic_s1_flag**[ i ] | u(1) |
|   } | |
|  } | |
| } | |

### 7.3.8 Slice segment data syntax

#### 7.3.8.1 General slice segment data syntax

| slice_segment_data( ) { | **Descriptor** |
|---|---|
|  do { | |
|   coding_tree_unit( ) | |
|   **end_of_slice_segment_flag** | ae(v) |
|   CtbAddrInTs++ | |
|   CtbAddrInRs = CtbAddrTsToRs[ CtbAddrInTs ] | |
|   if( !end_of_slice_segment_flag && ( ( tiles_enabled_flag && TileId[ CtbAddrInTs ] != TileId[ CtbAddrInTs − 1 ] ) \|\| ( entropy_coding_sync_enabled_flag && CtbAddrInTs % PicWidthInCtbsY = = 0 ) ) ) { | |
|    **end_of_sub_stream_one_bit** /* equal to 1 */ | ae(v) |
|    byte_alignment( ) | |
|   } | |
|  } while( !end_of_slice_segment_flag ) | |
| } | |

### 7.3.8.2 Coding tree unit syntax

| coding_tree_unit( ) { | **Descriptor** |
|---|---|
|     xCtb = ( CtbAddrInRs % PicWidthInCtbsY ) << CtbLog2SizeY | |
|     yCtb = ( CtbAddrInRs / PicWidthInCtbsY ) << CtbLog2SizeY | |
|     if( slice_sao_luma_flag \|\| slice_sao_chroma_flag ) | |
|         sao( xCtb >> CtbLog2SizeY, yCtb >> CtbLog2SizeY ) | |
|     coding_quadtree( xCtb, yCtb, CtbLog2SizeY, 0 ) | |
| } | |

### 7.3.8.3 Sample adaptive offset syntax

| sao( rx, ry ){ | **Descriptor** |
|---|---|
|   if( rx > 0 ) { | |
|     leftCtbInSliceSeg = CtbAddrInRs > SliceAddrRs | |
|     leftCtbInTile = TileId[ CtbAddrInTs ] = = TileId[ CtbAddrRsToTs[ CtbAddrInRs − 1 ] ] | |
|     if( leftCtbInSliceSeg && leftCtbInTile ) | |
|       **sao_merge_left_flag** | ae(v) |
|   } | |
|   if( ry > 0 && !sao_merge_left_flag ) { | |
|     upCtbInSliceSeg = ( CtbAddrInRs − PicWidthInCtbsY ) >= SliceAddrRs | |
|     upCtbInTile = TileId[ CtbAddrInTs ] = = TileId[ CtbAddrRsToTs[ CtbAddrInRs − PicWidthInCtbsY ] ] | |
|     if( upCtbInSliceSeg && upCtbInTile ) | |
|       **sao_merge_up_flag** | ae(v) |
|   } | |
|   if( !sao_merge_up_flag && !sao_merge_left_flag ) | |
|     for( cIdx = 0; cIdx < 3; cIdx++ ) | |
|       if( ( slice_sao_luma_flag && cIdx = = 0 ) \|\| ( slice_sao_chroma_flag && cIdx > 0 ) ) { | |
|         if( cIdx = = 0 ) | |
|           **sao_type_idx_luma** | ae(v) |
|         else if( cIdx = = 1 ) | |
|           **sao_type_idx_chroma** | ae(v) |
|         if( SaoTypeIdx[ cIdx ][ rx ][ ry ] != 0 ) { | |
|           for( i = 0; i < 4; i++ ) | |
|             **sao_offset_abs**[ cIdx ][ rx ][ ry ][ i ] | ae(v) |
|           if( SaoTypeIdx[ cIdx ][ rx ][ ry ] = = 1 ) { | |
|             for( i = 0; i < 4; i++ ) | |
|               if( sao_offset_abs[ cIdx ][ rx ][ ry ][ i ] != 0 ) | |
|                 **sao_offset_sign**[ cIdx ][ rx ][ ry ][ i ] | ae(v) |
|             **sao_band_position**[ cIdx ][ rx ][ ry ] | ae(v) |
|           } else { | |
|             if( cIdx = = 0 ) | |
|               **sao_eo_class_luma** | ae(v) |
|             if( cIdx = = 1 ) | |
|               **sao_eo_class_chroma** | ae(v) |
|           } | |
|         } | |
|       } | |
| } | |

### 7.3.8.4 Coding quadtree syntax

| coding_quadtree( x0, y0, log2CbSize, cqtDepth ) { | **Descriptor** |
|---|---|
|   if( x0 + ( 1 << log2CbSize ) <= pic_width_in_luma_samples && y0 + ( 1 << log2CbSize ) <= pic_height_in_luma_samples && log2CbSize > MinCbLog2SizeY ) | |
|     **split_cu_flag**[ x0 ][ y0 ] | ae(v) |
|   if( cu_qp_delta_enabled_flag && log2CbSize >= Log2MinCuQpDeltaSize ) { | |
|     IsCuQpDeltaCoded = 0 | |
|     CuQpDeltaVal = 0 | |
|   } | |
|   if( split_cu_flag[ x0 ][ y0 ] ) { | |
|     x1 = x0 + ( 1 << ( log2CbSize • 1 ) ) | |
|     y1 = y0 + ( 1 << ( log2CbSize • 1 ) ) | |
|     coding_quadtree( x0, y0, log2CbSize − 1, cqtDepth + 1 ) | |
|     if( x1 < pic_width_in_luma_samples ) | |
|       coding_quadtree( x1, y0, log2CbSize − 1, cqtDepth + 1 ) | |
|     if( y1 < pic_height_in_luma_samples ) | |
|       coding_quadtree( x0, y1, log2CbSize − 1, cqtDepth + 1 ) | |
|     if( x1 < pic_width_in_luma_samples && y1 < pic_height_in_luma_samples ) | |
|       coding_quadtree( x1, y1, log2CbSize − 1, cqtDepth + 1 ) | |
|   } else | |
|     coding_unit( x0, y0, log2CbSize ) | |
| } | |

#### 7.3.8.5 Coding unit syntax

| coding_unit( x0, y0, log2CbSize ) { | **Descriptor** |
|---|---|
|    if( transquant_bypass_enabled_flag ) | |
|        **cu_transquant_bypass_flag** | ae(v) |
|    if( slice_type != I ) | |
|        **cu_skip_flag**[ x0 ][ y0 ] | ae(v) |
|    nCbS = ( 1 << log2CbSize ) | |
|    if( cu_skip_flag[ x0 ][ y0 ] ) | |
|        prediction_unit( x0, y0, nCbS, nCbS ) | |
|    else { | |
|        if( slice_type != I ) | |
|            **pred_mode_flag** | ae(v) |
|        if( CuPredMode[ x0 ][ y0 ] != MODE_INTRA \|\| log2CbSize = = MinCbLog2SizeY ) | |
|            **part_mode** | ae(v) |
|        if( CuPredMode[ x0 ][ y0 ] = = MODE_INTRA ) { | |
|            if( PartMode = = PART_2Nx2N && pcm_enabled_flag &&                log2CbSize >= Log2MinIpcmCbSizeY &&                log2CbSize <= Log2MaxIpcmCbSizeY ) | |
|                **pcm_flag**[ x0 ][ y0 ] | ae(v) |
|            if( pcm_flag[ x0 ][ y0 ] ) { | |
|                while( !byte_aligned( ) ) | |
|                    **pcm_alignment_zero_bit** | f(1) |
|                pcm_sample( x0, y0, log2CbSize ) | |
|            } else { | |
|                pbOffset = ( PartMode = = PART_NxN ) ? ( nCbS / 2 ) : nCbS | |
|                for( j = 0; j < nCbS; j = j + pbOffset ) | |
|                    for( i = 0; i < nCbS; i = i + pbOffset ) | |
|                        **prev_intra_luma_pred_flag**[ x0 + i ][ y0 + j ] | ae(v) |
|                for( j = 0; j < nCbS; j = j + pbOffset ) | |
|                    for( i = 0; i < nCbS; i = i + pbOffset ) | |
|                        if( prev_intra_luma_pred_flag[ x0 + i ][ y0 + j ] ) | |
|                            **mpm_idx**[ x0 + i ][ y0 + j ] | ae(v) |
|                        else | |
|                            **rem_intra_luma_pred_mode**[ x0 + i ][ y0 + j ] | ae(v) |
|                **intra_chroma_pred_mode**[ x0 ][ y0 ] | ae(v) |
|            } | |
|        } else { | |
|            if( PartMode = = PART_2Nx2N ) | |
|                prediction_unit( x0, y0, nCbS, nCbS ) | |
|            else if( PartMode = = PART_2NxN ) { | |
|                prediction_unit( x0, y0, nCbS, nCbS / 2 ) | |
|                prediction_unit( x0, y0 + ( nCbS / 2 ), nCbS, nCbS / 2 ) | |
|            } else if( PartMode = = PART_Nx2N ) { | |
|                prediction_unit( x0, y0, nCbS / 2, nCbS ) | |
|                prediction_unit( x0 + ( nCbS / 2 ), y0, nCbS / 2, nCbS ) | |
|            } else if( PartMode = = PART_2NxnU ) { | |
|                prediction_unit( x0, y0, nCbS, nCbS / 4 ) | |
|                prediction_unit( x0, y0 + ( nCbS / 4 ), nCbS, nCbS * 3 / 4 ) | |
|            } else if( PartMode = = PART_2NxnD ) { | |
|                prediction_unit( x0, y0, nCbS, nCbS * 3 / 4 ) | |

| | |
|---|---|
|        prediction_unit( x0, y0 + ( nCbS * 3 / 4 ), nCbS, nCbS / 4 ) | |
|      } else if( PartMode = = PART_nLx2N ) { | |
|        prediction_unit( x0, y0, nCbS / 4, nCbS ) | |
|        prediction_unit( x0 + ( nCbS / 4 ), y0, nCbS * 3 / 4, nCbS ) | |
|      } else if( PartMode = = PART_nRx2N ) { | |
|        prediction_unit( x0, y0, nCbS * 3 / 4, nCbS ) | |
|        prediction_unit( x0 + ( nCbS * 3 / 4 ), y0, nCbS / 4, nCbS ) | |
|      } else { /* PART_NxN */ | |
|        prediction_unit( x0, y0, nCbS / 2, nCbS / 2 ) | |
|        prediction_unit( x0 + ( nCbS / 2 ), y0, nCbS / 2, nCbS / 2 ) | |
|        prediction_unit( x0, y0 + ( nCbS / 2 ), nCbS / 2, nCbS / 2 ) | |
|        prediction_unit( x0 + ( nCbS / 2 ), y0 + ( nCbS / 2 ), nCbS / 2, nCbS / 2 ) | |
|      } | |
|    } | |
|    if( !pcm_flag[ x0 ][ y0 ] ) { | |
|      if( CuPredMode[ x0 ][ y0 ] != MODE_INTRA &&<br>        !( PartMode = = PART_2Nx2N && merge_flag[ x0 ][ y0 ] ) ) | |
|        **rqt_root_cbf** | ae(v) |
|      if( rqt_root_cbf ) { | |
|        MaxTrafoDepth = ( CuPredMode[ x0 ][ y0 ] = = MODE_INTRA ?<br>                            ( max_transform_hierarchy_depth_intra + IntraSplitFlag ) :<br>                            max_transform_hierarchy_depth_inter ) | |
|        transform_tree( x0, y0, x0, y0, log2CbSize, 0, 0 ) | |
|      } | |
|    } | |
|  } | |
| } | |

### 7.3.8.6 Prediction unit syntax

| prediction_unit( x0, y0, nPbW, nPbH ) { | **Descriptor** |
|---|---|
|  if( cu_skip_flag[ x0 ][ y0 ] ) { | |
|   if( MaxNumMergeCand > 1 ) | |
|    **merge_idx**[ x0 ][ y0 ] | ae(v) |
|  } else { /* MODE_INTER */ | |
|   **merge_flag**[ x0 ][ y0 ] | ae(v) |
|   if( merge_flag[ x0 ][ y0 ] ) { | |
|    if( MaxNumMergeCand > 1 ) | |
|     **merge_idx**[ x0 ][ y0 ] | ae(v) |
|   } else { | |
|    if( slice_type = = B ) | |
|     **inter_pred_idc**[ x0 ][ y0 ] | ae(v) |
|    if( inter_pred_idc[ x0 ][ y0 ] != PRED_L1 ) { | |
|     if( num_ref_idx_l0_active_minus1 > 0 ) | |
|      **ref_idx_l0**[ x0 ][ y0 ] | ae(v) |
|     mvd_coding( x0, y0, 0 ) | |
|     **mvp_l0_flag**[ x0 ][ y0 ] | ae(v) |
|    } | |
|    if( inter_pred_idc[ x0 ][ y0 ] != PRED_L0 ) { | |
|     if( num_ref_idx_l1_active_minus1 > 0 ) | |
|      **ref_idx_l1**[ x0 ][ y0 ] | ae(v) |
|     if( mvd_l1_zero_flag && inter_pred_idc[ x0 ][ y0 ] = = PRED_BI ) { | |
|      MvdL1[ x0 ][ y0 ][ 0 ] = 0 | |
|      MvdL1[ x0 ][ y0 ][ 1 ] = 0 | |
|     } else | |
|      mvd_coding( x0, y0, 1 ) | |
|     **mvp_l1_flag**[ x0 ][ y0 ] | ae(v) |
|    } | |
|   } | |
|  } | |
| } | |

### 7.3.8.7 PCM sample syntax

| pcm_sample( x0, y0, log2CbSize ) { | **Descriptor** |
|---|---|
|  for( i = 0; i < 1 << ( log2CbSize << 1 ); i++ ) | |
|   **pcm_sample_luma**[ i ] | u(v) |
|  for( i = 0; i < ( 1 << ( log2CbSize << 1 ) ) >> 1; i++ ) | |
|   **pcm_sample_chroma**[ i ] | u(v) |
| } | |

### 7.3.8.8 Transform tree syntax

| transform_tree( x0, y0, xBase, yBase, log2TrafoSize, trafoDepth, blkIdx ) { | **Descriptor** |
|---|---|
|   if( log2TrafoSize <= Log2MaxTrafoSize && <br>     log2TrafoSize > Log2MinTrafoSize && <br>     trafoDepth < MaxTrafoDepth && !( IntraSplitFlag && ( trafoDepth = = 0 ) ) ) | |
|     **split_transform_flag**[ x0 ][ y0 ][ trafoDepth ] | ae(v) |
|   if( log2TrafoSize > 2 ) { | |
|     if( trafoDepth = = 0 \|\| cbf_cb[ xBase ][ yBase ][ trafoDepth − 1 ] ) | |
|       **cbf_cb**[ x0 ][ y0 ][ trafoDepth ] | ae(v) |
|     if( trafoDepth = = 0 \|\| cbf_cr[ xBase ][ yBase ][ trafoDepth − 1 ] ) | |
|       **cbf_cr**[ x0 ][ y0 ][ trafoDepth ] | ae(v) |
|   } | |
|   if( split_transform_flag[ x0 ][ y0 ][ trafoDepth ] ) { | |
|     x1 = x0 + ( 1 << ( log2TrafoSize • 1 ) ) | |
|     y1 = y0 + ( 1 << ( log2TrafoSize • 1 ) ) | |
|     transform_tree( x0, y0, x0, y0, log2TrafoSize − 1, trafoDepth + 1, 0 ) | |
|     transform_tree( x1, y0, x0, y0, log2TrafoSize − 1, trafoDepth + 1, 1 ) | |
|     transform_tree( x0, y1, x0, y0, log2TrafoSize − 1, trafoDepth + 1, 2 ) | |
|     transform_tree( x1, y1, x0, y0, log2TrafoSize − 1, trafoDepth + 1, 3 ) | |
|   } else { | |
|     if( CuPredMode[ x0 ][ y0 ] = = MODE_INTRA \|\| trafoDepth != 0 \|\| <br>         cbf_cb[ x0 ][ y0 ][ trafoDepth ] \|\| cbf_cr[ x0 ][ y0 ][ trafoDepth ] ) | |
|       **cbf_luma**[ x0 ][ y0 ][ trafoDepth ] | ae(v) |
|     transform_unit( x0, y0, xBase, yBase, log2TrafoSize, trafoDepth, blkIdx ) | |
|   } | |
| } | |

### 7.3.8.9 Motion vector difference syntax

| mvd_coding( x0, y0, refList ) { | **Descriptor** |
|---|---|
|   **abs_mvd_greater0_flag**[ 0 ] | ae(v) |
|   **abs_mvd_greater0_flag**[ 1 ] | ae(v) |
|   if( abs_mvd_greater0_flag[ 0 ] ) | |
|     **abs_mvd_greater1_flag**[ 0 ] | ae(v) |
|   if( abs_mvd_greater0_flag[ 1 ] ) | |
|     **abs_mvd_greater1_flag**[ 1 ] | ae(v) |
|   if( abs_mvd_greater0_flag[ 0 ] ) { | |
|     if( abs_mvd_greater1_flag[ 0 ] ) | |
|       **abs_mvd_minus2**[ 0 ] | ae(v) |
|     **mvd_sign_flag**[ 0 ] | ae(v) |
|   } | |
|   if( abs_mvd_greater0_flag[ 1 ] ) { | |
|     if( abs_mvd_greater1_flag[ 1 ] ) | |
|       **abs_mvd_minus2**[ 1 ] | ae(v) |
|     **mvd_sign_flag**[ 1 ] | ae(v) |
|   } | |
| } | |

### 7.3.8.10 Transform unit syntax

| transform_unit( x0, y0, xBase, yBase, log2TrafoSize, trafoDepth, blkIdx ) { | **Descriptor** |
|---|---|
|   if( cbf_luma[ x0 ][ y0 ][ trafoDepth ] \|\| cbf_cb[ x0 ][ y0 ][ trafoDepth ] \|\| cbf_cr[ x0 ][ y0 ][ trafoDepth ] ) { | |
|     if( cu_qp_delta_enabled_flag && !IsCuQpDeltaCoded ) { | |
|       **cu_qp_delta_abs** | ae(v) |
|       if( cu_qp_delta_abs ) | |
|         **cu_qp_delta_sign_flag** | ae(v) |
|     } | |
|     if( cbf_luma[ x0 ][ y0 ][ trafoDepth ] ) | |
|       residual_coding( x0, y0, log2TrafoSize, 0 ) | |
|     if( log2TrafoSize > 2 ) { | |
|       if( cbf_cb[ x0 ][ y0 ][ trafoDepth ] ) | |
|         residual_coding( x0, y0, log2TrafoSize − 1, 1 ) | |
|       if( cbf_cr[ x0 ][ y0 ][ trafoDepth ] ) | |
|         residual_coding( x0, y0, log2TrafoSize − 1, 2 ) | |
|     } else if( blkIdx = = 3 ) { | |
|       if( cbf_cb[ xBase ][ yBase ][ trafoDepth ] ) | |
|         residual_coding( xBase, yBase, log2TrafoSize, 1 ) | |
|       if( cbf_cr[ xBase ][ yBase ][ trafoDepth ] ) | |
|         residual_coding( xBase, yBase, log2TrafoSize, 2 ) | |
|     } | |
|   } | |
| } | |

### 7.3.8.11 Residual coding syntax

| residual_coding( x0, y0, log2TrafoSize, cIdx ) { | **Descriptor** |
|---|---|
|    if( transform_skip_enabled_flag  &&  !cu_transquant_bypass_flag  &&<br>       ( log2TrafoSize  = =  2 ) ) | |
|       **transform_skip_flag**[ x0 ][ y0 ][ cIdx ] | ae(v) |
|    **last_sig_coeff_x_prefix** | ae(v) |
|    **last_sig_coeff_y_prefix** | ae(v) |
|    if( last_sig_coeff_x_prefix > 3 ) | |
|       **last_sig_coeff_x_suffix** | ae(v) |
|    if( last_sig_coeff_y_prefix > 3 ) | |
|       **last_sig_coeff_y_suffix** | ae(v) |
|    lastScanPos = 16 | |
|    lastSubBlock = ( 1  <<  ( log2TrafoSize − 2 ) ) * ( 1  <<  ( log2TrafoSize − 2 ) ) − 1 | |
|    do { | |
|       if( lastScanPos  = =  0 ) { | |
|          lastScanPos = 16 | |
|          lastSubBlock− − | |
|       } | |
|       lastScanPos− − | |
|       xS = ScanOrder[ log2TrafoSize − 2 ][ scanIdx ][ lastSubBlock ][ 0 ] | |
|       yS = ScanOrder[ log2TrafoSize − 2 ][ scanIdx ][ lastSubBlock ][ 1 ] | |
|       xC = ( xS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ lastScanPos ][ 0 ] | |
|       yC = ( yS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ lastScanPos ][ 1 ] | |
|    } while( ( xC  !=  LastSignificantCoeffX ) \| \| ( yC  !=  LastSignificantCoeffY ) ) | |
|    for( i = lastSubBlock; i  >=  0; i− − ) { | |
|       xS = ScanOrder[ log2TrafoSize − 2 ][ scanIdx ][ i ][ 0 ] | |
|       yS = ScanOrder[ log2TrafoSize − 2 ][ scanIdx ][ i ][ 1 ] | |
|       inferSbDcSigCoeffFlag = 0 | |
|       if( ( i < lastSubBlock )  &&  ( i > 0 ) ) { | |
|          **coded_sub_block_flag**[ xS ][ yS ] | ae(v) |
|          inferSbDcSigCoeffFlag = 1 | |
|       } | |
|       for( n = ( i  = =  lastSubBlock ) ? lastScanPos − 1 : 15; n  >=  0; n− − ) { | |
|          xC = ( xS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 0 ] | |
|          yC = ( yS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 1 ] | |
|          if( coded_sub_block_flag[ xS ][ yS ]  &&  ( n > 0  \| \|  !inferSbDcSigCoeffFlag ) ) { | |
|             **sig_coeff_flag**[ xC ][ yC ] | ae(v) |
|             if( sig_coeff_flag[ xC ][ yC ] ) | |
|                inferSbDcSigCoeffFlag = 0 | |
|          } | |
|       } | |
|       firstSigScanPos = 16 | |
|       lastSigScanPos = −1 | |
|       numGreater1Flag = 0 | |
|       lastGreater1ScanPos = −1 | |
|       for( n = 15; n  >=  0; n− − ) { | |
|          xC = ( xS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 0 ] | |
|          yC = ( yS  <<  2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 1 ] | |
|          if( sig_coeff_flag[ xC ][ yC ] ) { | |

| | |
|---|---|
|         if( numGreater1Flag < 8 ) { | |
|           **coeff_abs_level_greater1_flag**[ n ] | ae(v) |
|           numGreater1Flag++ | |
|           if( coeff_abs_level_greater1_flag[ n ] && lastGreater1ScanPos = = −1 ) | |
|             lastGreater1ScanPos = n | |
|         } | |
|         if( lastSigScanPos = = −1 ) | |
|           lastSigScanPos = n | |
|         firstSigScanPos = n | |
|       } | |
|     } | |
|     signHidden = ( lastSigScanPos − firstSigScanPos > 3 && !cu_transquant_bypass_flag ) | |
|     if( lastGreater1ScanPos != −1 ) | |
|       **coeff_abs_level_greater2_flag**[ lastGreater1ScanPos ] | ae(v) |
|     for( n = 15; n >= 0; n− − ) { | |
|       xC = ( xS << 2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 0 ] | |
|       yC = ( yS << 2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 1 ] | |
|       if( sig_coeff_flag[ xC ][ yC ] &&<br>        ( !sign_data_hiding_enabled_flag \|\| !signHidden \|\| ( n != firstSigScanPos ) ) ) | |
|         **coeff_sign_flag**[ n ] | ae(v) |
|     } | |
|     numSigCoeff = 0 | |
|     sumAbsLevel = 0 | |
|     for( n = 15; n >= 0; n− − ) { | |
|       xC = ( xS << 2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 0 ] | |
|       yC = ( yS << 2 ) + ScanOrder[ 2 ][ scanIdx ][ n ][ 1 ] | |
|       if( sig_coeff_flag[ xC ][ yC ] ) { | |
|         baseLevel = 1 + coeff_abs_level_greater1_flag[ n ] +<br>                    coeff_abs_level_greater2_flag[ n ] | |
|         if( baseLevel = = ( ( numSigCoeff < 8 ) ?<br>                    ( (n = = lastGreater1ScanPos) ? 3 : 2 ) : 1 ) ) | |
|           **coeff_abs_level_remaining**[ n ] | ae(v) |
|         TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ] =<br>          ( coeff_abs_level_remaining[ n ] + baseLevel ) * ( 1 − 2 * coeff_sign_flag[ n ] ) | |
|         if( sign_data_hiding_enabled_flag && signHidden ) { | |
|           sumAbsLevel += ( coeff_abs_level_remaining[ n ] + baseLevel ) | |
|           if( ( n = = firstSigScanPos ) && ( ( sumAbsLevel % 2 ) = = 1 ) ) | |
|             TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ] =<br>                    −TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ] | |
|         } | |
|         numSigCoeff++ | |
|       } | |
|     } | |
|   } | |
| } | |

## 7.4 Semantics

### 7.4.1 General

Semantics associated with the syntax structures and with the syntax elements within these structures are specified in this subclause. When the semantics of a syntax element are specified using a table or a set of tables, any values that are not specified in the table(s) shall not be present in the bitstream unless otherwise specified in this Specification.

### 7.4.2 NAL unit semantics

#### 7.4.2.1 General NAL unit semantics

NumBytesInNalUnit specifies the size of the NAL unit in bytes. This value is required for decoding of the NAL unit. Some form of demarcation of NAL unit boundaries is necessary to enable inference of NumBytesInNalUnit. One such demarcation method is specified in Annex B for the byte stream format. Other methods of demarcation may be specified outside of this Specification.

NOTE 1 – The VCL is specified to efficiently represent the content of the video data. The NAL is specified to format that data and provide header information in a manner appropriate for conveyance on a variety of communication channels or storage media. All data are contained in NAL units, each of which contains an integer number of bytes. A NAL unit specifies a generic format for use in both packet-oriented and bitstream systems. The format of NAL units for both packet-oriented transport and byte stream is identical except that each NAL unit can be preceded by a start code prefix and extra padding bytes in the byte stream format specified in Annex B.

**rbsp_byte**[ i ] is the i-th byte of an RBSP. An RBSP is specified as an ordered sequence of bytes as follows:

The RBSP contains an SODB as follows:

– If the SODB is empty (i.e. zero bits in length), the RBSP is also empty.

– Otherwise, the RBSP contains the SODB as follows:

  1) The first byte of the RBSP contains the (most significant, left-most) eight bits of the SODB; the next byte of the RBSP contains the next eight bits of the SODB, etc., until fewer than eight bits of the SODB remain.

  2) rbsp_trailing_bits( ) are present after the SODB as follows:

    i) The first (most significant, left-most) bits of the final RBSP byte contains the remaining bits of the SODB (if any).

    ii) The next bit consists of a single rbsp_stop_one_bit equal to 1.

    iii) When the rbsp_stop_one_bit is not the last bit of a byte-aligned byte, one or more rbsp_alignment_zero_bit is present to result in byte alignment.

  3) One or more cabac_zero_word 16-bit syntax elements equal to 0x0000 may be present in some RBSPs after the rbsp_trailing_bits( ) at the end of the RBSP.

Syntax structures having these RBSP properties are denoted in the syntax tables using an "_rbsp" suffix. These structures are carried within NAL units as the content of the rbsp_byte[ i ] data bytes. The association of the RBSP syntax structures to the NAL units is as specified in Table 7-1.

NOTE 2 – When the boundaries of the RBSP are known, the decoder can extract the SODB from the RBSP by concatenating the bits of the bytes of the RBSP and discarding the rbsp_stop_one_bit, which is the last (least significant, right-most) bit equal to 1, and discarding any following (less significant, farther to the right) bits that follow it, which are equal to 0. The data necessary for the decoding process is contained in the SODB part of the RBSP.

**emulation_prevention_three_byte** is a byte equal to 0x03. When an emulation_prevention_three_byte is present in the NAL unit, it shall be discarded by the decoding process.

The last byte of the NAL unit shall not be equal to 0x00.

Within the NAL unit, the following three-byte sequences shall not occur at any byte-aligned position:

– 0x000000

– 0x000001

– 0x000002

Within the NAL unit, any four-byte sequence that starts with 0x000003 other than the following sequences shall not occur at any byte-aligned position:

– 0x00000300

– 0x00000301

– 0x00000302

– 0x00000303

### 7.4.2.2 NAL unit header semantics

**forbidden_zero_bit** shall be equal to 0.

**nal_unit_type** specifies the type of RBSP data structure contained in the NAL unit as specified in Table 7-1.

NAL units that have nal_unit_type in the range of UNSPEC48..UNSPEC63, inclusive, for which semantics are not specified, shall not affect the decoding process specified in this Specification.

NOTE 1 – NAL unit types in the range of UNSPEC48..UNSPEC63 may be used as determined by the application. No decoding process for these values of nal_unit_type is specified in this Specification. Since different applications might use these NAL unit types for different purposes, particular care must be exercised in the design of encoders that generate NAL units with these nal_unit_type values, and in the design of decoders that interpret the content of NAL units with these nal_unit_type values.

For purposes other than determining the amount of data in the decoding units of the bitstream (as specified in Annex C), decoders shall ignore (remove from the bitstream and discard) the contents of all NAL units that use reserved values of nal_unit_type.

NOTE 2 – This requirement allows future definition of compatible extensions to this Specification.

**Table 7-1 – NAL unit type codes and NAL unit type classes**

| nal_unit_type | Name of nal_unit_type | Content of NAL unit and RBSP syntax structure | NAL unit type class |
|---|---|---|---|
| 0<br>1 | TRAIL_N<br>TRAIL_R | Coded slice segment of a non-TSA, non-STSA trailing picture<br>slice_segment_layer_rbsp( ) | VCL |
| 2<br>3 | TSA_N<br>TSA_R | Coded slice segment of a TSA picture<br>slice_segment_layer_rbsp( ) | VCL |
| 4<br>5 | STSA_N<br>STSA_R | Coded slice segment of an STSA picture<br>slice_segment_layer_rbsp( ) | VCL |
| 6<br>7 | RADL_N<br>RADL_R | Coded slice segment of a RADL picture<br>slice_segment_layer_rbsp( ) | VCL |
| 8<br>9 | RASL_N<br>RASL_R | Coded slice segment of a RASL picture<br>slice_segment_layer_rbsp( ) | VCL |
| 10<br>12<br>14 | RSV_VCL_N10<br>RSV_VCL_N12<br>RSV_VCL_N14 | Reserved non-IRAP sub-layer non-reference VCL NAL unit types | VCL |
| 11<br>13<br>15 | RSV_VCL_R11<br>RSV_VCL_R13<br>RSV_VCL_R15 | Reserved non-IRAP sub-layer reference VCL NAL unit types | VCL |
| 16<br>17<br>18 | BLA_W_LP<br>BLA_W_RADL<br>BLA_N_LP | Coded slice segment of a BLA picture<br>slice_segment_layer_rbsp( ) | VCL |
| 19<br>20 | IDR_W_RADL<br>IDR_N_LP | Coded slice segment of an IDR picture<br>slice_segment_layer_rbsp( ) | VCL |
| 21 | CRA_NUT | Coded slice segment of a CRA picture<br>slice_segment_layer_rbsp( ) | VCL |
| 22<br>23 | RSV_IRAP_VCL22<br>RSV_IRAP_VCL23 | Reserved IRAP VCL NAL unit types | VCL |
| 24..31 | RSV_VCL24..<br>RSV_VCL31 | Reserved non-IRAP VCL NAL unit types | VCL |
| 32 | VPS_NUT | Video parameter set<br>video_parameter_set_rbsp( ) | non-VCL |
| 33 | SPS_NUT | Sequence parameter set<br>seq_parameter_set_rbsp( ) | non-VCL |
| 34 | PPS_NUT | Picture parameter set<br>pic_parameter_set_rbsp( ) | non-VCL |
| 35 | AUD_NUT | Access unit delimiter<br>access_unit_delimiter_rbsp( ) | non-VCL |
| 36 | EOS_NUT | End of sequence<br>end_of_seq_rbsp( ) | non-VCL |
| 37 | EOB_NUT | End of bitstream<br>end_of_bitstream_rbsp( ) | non-VCL |
| 38 | FD_NUT | Filler data<br>filler_data_rbsp( ) | non-VCL |
| 39<br>40 | PREFIX_SEI_NUT<br>SUFFIX_SEI_NUT | Supplemental enhancement information<br>sei_rbsp( ) | non-VCL |
| 41..47 | RSV_NVCL41..<br>RSV_NVCL47 | Reserved | non-VCL |

| | | | |
|---|---|---|---|
| 48..63 | UNSPEC48..<br>UNSPEC63 | Unspecified | non-VCL |

NOTE 3 – A CRA picture may have associated RASL or RADL pictures present in the bitstream.

NOTE 4 – A BLA picture having nal_unit_type equal to BLA_W_LP may have associated RASL or RADL pictures present in the bitstream. A BLA picture having nal_unit_type equal to BLA_W_RADL does not have associated RASL pictures present in the bitstream, but may have associated RADL pictures in the bitstream. A BLA picture having nal_unit_type equal to BLA_N_LP does not have associated leading pictures present in the bitstream.

NOTE 5 – An IDR picture having nal_unit_type equal to IDR_N_LP does not have associated leading pictures present in the bitstream. An IDR picture having nal_unit_type equal to IDR_W_RADL does not have associated RASL pictures present in the bitstream, but may have associated RADL pictures in the bitstream.

NOTE 6 – A sub-layer non-reference picture is not included in any of RefPicSetStCurrBefore, RefPicSetStCurrAfter and RefPicSetLtCurr of any picture with the same value of TemporalId, and may be discarded without affecting the decodability of other pictures with the same value of TemporalId.

All coded slice segment NAL units of an access unit shall have the same value of nal_unit_type. A picture or an access unit is also referred to as having a nal_unit_type equal to the nal_unit_type of the coded slice segment NAL units of the picture or access unit.

If a picture has nal_unit_type equal to TRAIL_N, TSA_N, STSA_N, RADL_N, RASL_N, RSV_VCL_N10, RSV_VCL_N12, or RSV_VCL_N14, the picture is a sub-layer non-reference picture. Otherwise, the picture is a sub-layer reference picture.

Each picture, other than the first picture in the bitstream in decoding order, is considered to be associated with the previous IRAP picture in decoding order.

When a picture is a leading picture, it shall be a RADL or RASL picture.

When a picture is a trailing picture, it shall not be a RADL or RASL picture.

When a picture is a leading picture, it shall precede, in decoding order, all trailing pictures that are associated with the same IRAP picture.

No RASL pictures shall be present in the bitstream that are associated with a BLA picture having nal_unit_type equal to BLA_W_RADL or BLA_N_LP.

No RASL pictures shall be present in the bitstream that are associated with an IDR picture.

No RADL pictures shall be present in the bitstream that are associated with a BLA picture having nal_unit_type equal to BLA_N_LP or that are associated with an IDR picture having nal_unit_type equal to IDR_N_LP.

NOTE 7 – It is possible to perform random access at the position of an IRAP access unit by discarding all access units before the IRAP access unit (and to correctly decode the IRAP picture and all the subsequent non-RASL pictures in decoding order), provided each parameter set is available (either in the bitstream or by external means not specified in this Specification) when it needs to be activated.

Any picture that has PicOutputFlag equal to 1 that precedes an IRAP picture in decoding order shall precede the IRAP picture in output order and shall precede any RADL picture associated with the IRAP picture in output order.

Any RASL picture associated with a CRA or BLA picture shall precede any RADL picture associated with the CRA or BLA picture in output order.

Any RASL picture associated with a CRA picture shall follow, in output order, any IRAP picture that precedes the CRA picture in decoding order.

When sps_temporal_id_nesting_flag is equal to 1 and TemporalId is greater than 0, the nal_unit_type shall be equal to TSA_R, TSA_N, RADL_R, RADL_N, RASL_R, or RASL_N.

**nuh_layer_id** shall be equal to 0. Other values of nuh_layer_id may be specified in the future by ITU-T | ISO/IEC. For purposes other than determining the amount of data in the decoding units of the bitstream (as specified in Annex C), decoders shall ignore (i.e. remove from the bitstream and discard) all NAL units with values of nuh_layer_id not equal to 0.

NOTE 8 – It is anticipated that in future scalable or 3D video coding extensions of this specification, this syntax element will be used to identify additional layers that may be present in the CVS, wherein a layer may be, e.g. a spatial scalable layer, a quality scalable layer, a texture view or a depth view.

**nuh_temporal_id_plus1** minus 1 specifies a temporal identifier for the NAL unit. The value of nuh_temporal_id_plus1 shall not be equal to 0.

The variable TemporalId is specified as follows:

$$\text{TemporalId} = \text{nuh\_temporal\_id\_plus1} - 1 \qquad (7\text{-}1)$$

If nal_unit_type is in the range of BLA_W_LP to RSV_IRAP_VCL23, inclusive, i.e. the coded slice segment belongs to an IRAP picture, TemporalId shall be equal to 0. Otherwise, when nal_unit_type is equal to TSA_R, TSA_N, STSA_R, or STSA_N, TemporalId shall not be equal to 0.

The value of TemporalId shall be the same for all VCL NAL units of an access unit. The value of TemporalId of an access unit is the value of the TemporalId of the VCL NAL units of the access unit.

The value of TemporalId for non-VCL NAL units is constrained as follows:

– If nal_unit_type is equal to VPS_NUT or SPS_NUT, TemporalId shall be equal to 0 and the TemporalId of the access unit containing the NAL unit shall be equal to 0.

– Otherwise if nal_unit_type is equal to EOS_NUT or EOB_NUT, TemporalId shall be equal to 0.

– Otherwise, if nal_unit_type is equal to AUD_NUT or FD_NUT, TemporalId shall be equal to the TemporalId of the access unit containing the NAL unit.

– Otherwise, TemporalId shall be greater than or equal to the TemporalId of the access unit containing the NAL unit.

NOTE 9 – When the NAL unit is a non-VCL NAL unit, the value of TemporalId is equal to the minimum value of the TemporalId values of all access units to which the non-VCL NAL unit applies. When nal_unit_type is equal to PPS_NUT, TemporalId may be greater than or equal to the TemporalId of the containing access unit, as all PPSs may be included in the beginning of a bitstream, wherein the first coded picture has TemporalId equal to 0. When nal_unit_type is equal to PREFIX_SEI_NUT or SUFFIX_SEI_NUT, TemporalId may be greater than or equal to the TemporalId of the containing access unit, as an SEI NAL unit may contain information, e.g. in a buffering period SEI message or a picture timing SEI message, that applies to a bitstream subset that includes access units for which the TemporalId values are greater than the TemporalId of the access unit containing the SEI NAL unit.

### 7.4.2.3 Encapsulation of an SODB within an RBSP (informative)

This subclause does not form an integral part of this Specification.

The form of encapsulation of an SODB within an RBSP and the use of the emulation_prevention_three_byte for encapsulation of an RBSP within a NAL unit is described for the following purposes:

– To prevent the emulation of start codes within NAL units while allowing any arbitrary SODB to be represented within a NAL unit,

– To enable identification of the end of the SODB within the NAL unit by searching the RBSP for the rbsp_stop_one_bit starting at the end of the RBSP,

– To enable a NAL unit to have a size greater than that of the SODB under some circumstances (using one or more cabac_zero_word syntax elements).

The encoder can produce a NAL unit from an RBSP by the following procedure:

1. The RBSP data are searched for byte-aligned bits of the following binary patterns:

   '00000000 00000000 000000xx' (where 'xx' represents any two-bit pattern: '00', '01', '10', or '11'),

   and a byte equal to 0x03 is inserted to replace the bit pattern with the pattern:

   '00000000 00000000 00000011 000000xx',

   and finally, when the last byte of the RBSP data is equal to 0x00 (which can only occur when the RBSP ends in a cabac_zero_word), a final byte equal to 0x03 is appended to the end of the data. The last zero byte of a byte-aligned three-byte sequence 0x000000 in the RBSP (which is replaced by the four-byte sequence 0x00000300) is taken into account when searching the RBSP data for the next occurrence of byte-aligned bits with the binary patterns specified above.

2. The resulting sequence of bytes is then prefixed with the NAL unit header, within which the nal_unit_type indicates the type of RBSP data structure in the NAL unit.

The process specified above results in the construction of the entire NAL unit.

This process can allow any SODB to be represented in a NAL unit while ensuring both of the following:

– No byte-aligned start code prefix is emulated within the NAL unit.

– No sequence of 8 zero-valued bits followed by a start code prefix, regardless of byte-alignment, is emulated within the NAL unit.

### 7.4.2.4 Order of NAL units and association to coded pictures, access units, and coded video sequences

#### 7.4.2.4.1 General

This subclause specifies constraints on the order of NAL units in the bitstream.

Any order of NAL units in the bitstream obeying these constraints is referred to in the text as the decoding order of NAL units. Within a NAL unit, the syntax in subclauses 7.3, D.2, and E.1 specifies the decoding order of syntax elements. Decoders shall be capable of receiving NAL units and their syntax elements in decoding order.

#### 7.4.2.4.2 Order of VPS, SPS and PPS RBSPs and their activation

This subclause specifies the activation process of VPSs, SPSs, and PPSs.

NOTE 1 – The VPS, SPS, and PPS mechanism decouples the transmission of infrequently changing information from the transmission of coded block data. VPSs, SPSs, and PPSs may, in some applications, be conveyed "out-of-band".

A PPS RBSP includes parameters that can be referred to by the coded slice segment NAL units of one or more coded pictures. Each PPS RBSP is initially considered not active at the start of the operation of the decoding process. At most one PPS RBSP is considered active at any given moment during the operation of the decoding process, and the activation of any particular PPS RBSP results in the deactivation of the previously-active PPS RBSP (if any).

When a PPS RBSP (with a particular value of pps_pic_parameter_set_id) is not active and it is referred to by a coded slice segment NAL unit (using a value of slice_pic_parameter_set_id equal to the pps_pic_parameter_set_id value), it is activated. This PPS RBSP is called the active PPS RBSP until it is deactivated by the activation of another PPS RBSP. A PPS RBSP, with that particular value of pps_pic_parameter_set_id, shall be available to the decoding process prior to its activation, included in at least one access unit with TemporalId less than or equal to the TemporalId of the PPS NAL unit or provided through external means.

Any PPS NAL unit containing the value of pps_pic_parameter_set_id for the active PPS RBSP for a coded picture shall have the same content as that of the active PPS RBSP for the coded picture, unless it follows the last VCL NAL unit of the coded picture and precedes the first VCL NAL unit of another coded picture.

An SPS RBSP includes parameters that can be referred to by one or more PPS RBSPs or one or more SEI NAL units containing an active parameter sets SEI message. Each SPS RBSP is initially considered not active at the start of the operation of the decoding process. At most one SPS RBSP is considered active at any given moment during the operation of the decoding process, and the activation of any particular SPS RBSP results in the deactivation of the previously-active SPS RBSP (if any).

When an SPS RBSP (with a particular value of sps_seq_parameter_set_id) is not already active and it is referred to by activation of a PPS RBSP (in which pps_seq_parameter_set_id is equal to the sps_seq_parameter_set_id value) or is referred to by an SEI NAL unit containing an active parameter sets SEI message (in which active_seq_parameter_set_id[ 0 ] is equal to the sps_seq_parameter_set_id value), it is activated. This SPS RBSP is called the active SPS RBSP until it is deactivated by the activation of another SPS RBSP. An SPS RBSP, with that particular value of sps_seq_parameter_set_id, shall be available to the decoding process prior to its activation, included in at least one access unit with TemporalId equal to 0 or provided through external means. An activated SPS RBSP shall remain active for the entire CVS.

NOTE 2 – Because an IRAP access unit with NoRaslOutputFlag equal to 1 begins a new CVS and an activated SPS RBSP must remain active for the entire CVS, an SPS RBSP can only be activated by an active parameter sets SEI message when the active parameter sets SEI message is part of an IRAP access unit with NoRaslOutputFlag equal to 1.

Any SPS NAL unit containing the value of sps_seq_parameter_set_id for the active SPS RBSP for a CVS shall have the same content as that of the active SPS RBSP for the CVS, unless it follows the last access unit of the CVS and precedes the first VCL NAL unit and the first SEI NAL unit containing an active parameter sets SEI message (when present) of another CVS.

A VPS RBSP includes parameters that can be referred to by one or more SPS RBSPs or one or more SEI NAL units containing an active parameter sets SEI message. Each VPS RBSP is initially considered not active at the start of the operation of the decoding process. At most one VPS RBSP is considered active at any given moment during the operation of the decoding process, and the activation of any particular VPS RBSP results in the deactivation of the previously-active VPS RBSP (if any).

When a VPS RBSP (with a particular value of vps_video_parameter_set_id) is not already active and it is referred to by activation of an SPS RBSP (in which sps_video_parameter_set_id is equal to the vps_video_parameter_set_id value), or is referred to by an SEI NAL unit containing an active parameter sets SEI message (in which active_video_parameter_set_id is equal to the vps_video_parameter_set_id value), it is activated. This VPS RBSP is called the active VPS RBSP until it is deactivated by the activation of another VPS RBSP. A VPS RBSP, with that particular value of vps_video_parameter_set_id, shall be available to the decoding process prior to its activation, included in at least one access unit with TemporalId equal to 0 or provided through external means. An activated VPS RBSP shall remain active for the entire CVS.

NOTE 3 – Because an IRAP access unit with NoRaslOutputFlag equal to 1 begins a new CVS and an activated VPS RBSP must remain active for the entire CVS, a VPS RBSP can only be activated by an active parameter sets SEI message when the active parameter sets SEI message is part of an IRAP access unit with NoRaslOutputFlag equal to 1.

Any VPS NAL unit containing the value of vps_video_parameter_set_id for the active VPS RBSP for a CVS shall have the same content as that of the active VPS RBSP for the CVS, unless it follows the last access unit of the CVS and precedes the first VCL NAL unit, the first SPS NAL unit, and the first SEI NAL unit containing an active parameter sets SEI message (when present) of another CVS.

NOTE 4 – If VPS RBSP, SPS RBSP, or PPS RBSP are conveyed within the bitstream, these constraints impose an order constraint on the NAL units that contain the VPS RBSP, SPS RBSP, or PPS RBSP, respectively. Otherwise (VPS RBSP, SPS RBSP, or PPS RBSP are conveyed by other means not specified in this Specification), they must be available to the decoding process in a timely fashion such that these constraints are obeyed.

All constraints that are expressed on the relationship between the values of the syntax elements and the values of variables derived from those syntax elements in VPSs, SPSs, and PPSs and other syntax elements are expressions of constraints that apply only to the active VPS, the active SPS, and the active PPS. If any VPS RBSP, SPS RBSP, and PPS RBSP is present that is never activated in the bitstream, its syntax elements shall have values that would conform to the specified constraints if it was activated by reference in an otherwise conforming bitstream.

During operation of the decoding process (see clause 8), the values of parameters of the active VPS, the active SPS, and the active PPS RBSP are considered in effect. For interpretation of SEI messages, the values of the active VPS, the active SPS, and the active PPS RBSP for the operation of the decoding process for the VCL NAL units of the coded picture in the same access unit are considered in effect unless otherwise specified in the SEI message semantics.

### 7.4.2.4.3 Order of access units and association to CVSs

A bitstream conforming to this Specification consists of one or more CVSs.

A CVS consists of one or more access units. The order of NAL units and coded pictures and their association to access units is described in subclause 7.4.2.4.4.

The first access unit of a CVS is an IRAP access unit with NoRaslOutputFlag equal to 1.

It is a requirement of bitstream conformance that, when present, the next access unit after an access unit that contains an end of sequence NAL unit or an end of bitstream NAL unit shall be an IRAP access unit, which may be an IDR access unit, a BLA access unit, or a CRA access unit.

### 7.4.2.4.4 Order of NAL units and coded pictures and their association to access units

This subclause specifies the order of NAL units and coded pictures and their association to access unit for CVSs that conform to one or more of the profiles specified in Annex A that are decoded using the decoding process specified in clauses 2 through 10.

An access unit consists of one coded picture and zero or more non-VCL NAL units. The association of VCL NAL units to coded pictures is described in subclause 7.4.2.4.5.

The first access unit in the bitstream starts with the first NAL unit of the bitstream.

The first of any of the following NAL units after the last VCL NAL unit of a coded picture specifies the start of a new access unit:

– access unit delimiter NAL unit (when present),

– VPS NAL unit (when present),

– SPS NAL unit (when present),

– PPS NAL unit (when present),

– Prefix SEI NAL unit (when present),

– NAL units with nal_unit_type in the range of RSV_NVCL41..RSV_NVCL44 (when present),

– NAL units with nal_unit_type in the range of UNSPEC48..UNSPEC55 (when present),

– first VCL NAL unit of a coded picture (always present).

The order of the coded pictures and non-VCL NAL units within an access unit shall obey the following constraints:

– When an access unit delimiter NAL unit is present, it shall be the first NAL unit. There shall be at most one access unit delimiter NAL unit in any access unit.

– When any prefix SEI NAL units are present, they shall not follow the last VCL NAL unit of the access unit.

– NAL units having nal_unit_type equal to FD_NUT or SUFFIX_SEI_NUT, or in the range of RSV_NVCL45..RSV_NVCL47 or UNSPEC56..UNSPEC63 shall not precede the first VCL NAL unit of the coded picture.

– When an end of sequence NAL unit is present, it shall be the last NAL unit in the access unit other than an end of bitstream NAL unit (when present).

– When an end of bitstream NAL unit is present, it shall be the last NAL unit in the access unit.

NOTE – VPS NAL units, SPS NAL units, PPS NAL units, prefix SEI NAL units, or NAL units with nal_unit_type in the range of RSV_NVCL41..RSV_NVCL44 or UNSPEC48..UNSPEC55, may be present in an access unit, but cannot follow the last VCL NAL unit of the coded picture within the access unit, as this condition would specify the start of a new access unit.

The structure of access units not containing any NAL units with nal_unit_type equal to FD_NUT, VPS_NUT, SPS_NUT, PPS_NUT, RSV_VCL_N10, RSV_VCL_R11, RSV_VCL_N12, RSV_VCL_R13, RSV_VCL_N14, or RSV_VCL_R15, RSV_IRAP_VCL22, or RSV_IRAP_VCL23, or in the range of RSV_VCL24..RSV_VCL31, RSV_NVCL41..RSV_NVCL47, or UNSPEC48..UNSPEC63 is shown in Figure 7-1.

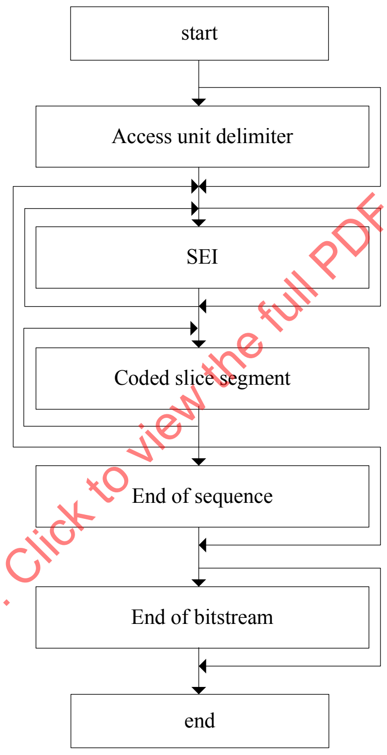


**Figure 7-1 – Structure of an access unit not containing any NAL units with nal_unit_type equal to FD_NUT, SUFFIX_SEI_NUT, VPS_NUT, SPS_NUT, PPS_NUT, RSV_VCL_N10, RSV_VCL_R11, RSV_VCL_N12, RSV_VCL_R13, RSV_VCL_N14, RSV_VCL_R15, RSV_IRAP_VCL22, or RSV_IRAP_VCL23, or in the range of RSV_VCL24..RSV_VCL31, RSV_NVCL41..RSV_NVCL47, or UNSPEC48..UNSPEC63**

### 7.4.2.4.5 Order of VCL NAL units and association to coded pictures

This subclause specifies the order of VCL NAL units and association to coded pictures.

Each VCL NAL unit is part of a coded picture.

The order of the VCL NAL units within a coded picture is constrained as follows:

– The first VCL NAL unit of the coded picture shall have first_slice_segment_in_pic_flag equal to 1.

– Let sliceSegAddrA and sliceSegAddrB be the slice_segment_address values of any two coded slice segment NAL units A and B within the same coded picture. When either of the following conditions is true, coded slice segment NAL unit A shall precede the coded slice segment NAL unit B:

– TileId[ CtbAddrRsToTs[ sliceSegAddrA ] ] is less than TileId[ CtbAddrRsToTs[ sliceSegAddrB ] ].

– TileId[ CtbAddrRsToTs[ sliceSegAddrA ] ] is equal to TileId[ CtbAddrRsToTs[ sliceSegAddrB ] ] and CtbAddrRsToTs[ sliceSegAddrA ] is less than CtbAddrRsToTs[ sliceSegAddrB ].

### 7.4.3 Raw byte sequence payloads, trailing bits, and byte alignment semantics

#### 7.4.3.1 Video parameter set RBSP semantics

NOTE 1 – VPS NAL units are required to be available to the decoding process prior to their activation (either in the bitstream or by external means), as specified in subclause 7.4.2.4.2. However, the VPS RBSP contains information that is not necessary for operation of the decoding process of this version of this Specification. For purposes other than determining the amount of data in the decoding units of the bitstream (as specified in Annex C), decoders conforming to this version of this Specification may ignore (remove from the bitstream and discard) the content of all VPS NAL units.

Any two instances of the syntax structure hrd_parameters( ) included in a VPS RBSP shall not have the same content.

**vps_video_parameter_set_id** identifies the VPS for reference by other syntax elements.

**vps_reserved_three_2bits** shall be equal to 3 in bitstreams conforming to this version of this Specification. Other values for vps_reserved_three_2bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of vps_reserved_three_2bits.

**vps_max_layers_minus1** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for vps_ max_layers_minus1 are reserved for future use by ITU-T | ISO/IEC. Although the value of vps_max_layers_minus1 is required to be equal to 0 in this version of this Specification, decoders shall allow other values of vps_max_layers_minus1 to appear in the syntax.

NOTE 2 – It is anticipated that in future scalable or 3D video coding extensions of this Specification, this field will be used to specify the maximum number of layers that may be present in the CVS, wherein a layer may e.g. be a spatial scalable layer, a quality scalable layer, a texture view or a depth view.

**vps_max_sub_layers_minus1** plus 1 specifies the maximum number of temporal sub-layers that may be present in the bitstream. The value of vps_max_sub_layers_minus1 shall be in the range of 0 to 6, inclusive.

**vps_temporal_id_nesting_flag**, when vps_max_sub_layers_minus1 is greater than 0, specifies whether inter prediction is additionally restricted for CVSs referring to the VPS. When vps_max_sub_layers_minus1 is equal to 0, vps_temporal_id_nesting_flag shall be equal to 1.

NOTE 3 – The syntax element vps_temporal_id_nesting_flag is used to indicate that temporal sub-layer up-switching, i.e. switching from decoding of up to any TemporalId tIdN to decoding up to any TemporalId tIdM that is greater than tIdN, is always possible.

**vps_reserved_0xffff_16bits** shall be equal to 0xFFFF in bitstreams conforming to this version of this Specification. Other values for vps_reserved_0xffff_16bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of vps_reserved_0xffff_16bits.

NOTE 4 – It is anticipated that in future scalable or 3D video coding extensions of this Specification, this this syntax element will specify a byte offset to the next set of fixed-length coded information in the VPS RBSP, within the data currently specified as vps_extension_data_flag syntax elements. The byte offset would then help to locate and access such information in the VPS RBSP without the need for performing entropy decoding.

**vps_sub_layer_ordering_info_present_flag** equal to 1 specifies that vps_max_dec_pic_buffering_minus1[ i ], vps_max_num_reorder_pics[ i ], and vps_max_latency_increase_plus1[ i ] are present for vps_max_sub_layers_minus1 + 1 sub-layers. vps_sub_layer_ordering_info_present_flag equal to 0 specifies that the values of vps_max_dec_pic_buffering_minus1[ vps_max_sub_layers_minus1 ], vps_max_num_reorder_pics[ vps_max_sub_layers_minus1 ], and vps_max_latency_increase_plus1[ vps_max_sub_layers_minus1 ] apply to all sub-layers.

**vps_max_dec_pic_buffering_minus1**[ i ] plus 1 specifies the maximum required size of the decoded picture buffer for the CVS in units of picture storage buffers when HighestTid is equal to i. The value of vps_max_dec_pic_buffering_minus1[ i ] shall be in the range of 0 to MaxDpbSize − 1 (as specified in subclause A.4), inclusive. When i is greater than 0, vps_max_dec_pic_buffering_minus1[ i ] shall be greater than or equal to vps_max_dec_pic_buffering_minus1[ i − 1 ]. When vps_max_dec_pic_buffering_minus1[ i ] is not present for i in the range of 0 to vps_max_sub_layers_minus1 − 1, inclusive, due to vps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to vps_max_dec_pic_buffering_minus1[ vps_max_sub_layers_minus1 ].

**vps_max_num_reorder_pics**[ i ] indicates the maximum allowed number of pictures that can precede any picture in the CVS in decoding order and follow that picture in output order when HighestTid is equal to i. The value of vps_max_num_reorder_pics[ i ] shall be in the range of 0 to vps_max_dec_pic_buffering_minus1[ i ], inclusive. When i is greater than 0, vps_max_num_reorder_pics[ i ] shall be greater than or equal to vps_max_num_reorder_pics[ i − 1 ]. When vps_max_num_reorder_pics[ i ] is not present for i in the range of 0 to vps_max_sub_layers_minus1 − 1, inclusive, due to vps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to vps_max_num_reorder_pics[ vps_max_sub_layers_minus1 ].

**vps_max_latency_increase_plus1**[ i ] not equal to 0 is used to compute the value of VpsMaxLatencyPictures[ i ], which specifies the maximum number of pictures that can precede any picture in the CVS in output order and follow that picture in decoding order when HighestTid is equal to i.

When vps_max_latency_increase_plus1[ i ] is not equal to 0, the value of VpsMaxLatencyPictures[ i ] is specified as follows:

$$\text{VpsMaxLatencyPictures[ i ]} = \text{vps\_max\_num\_reorder\_pics[ i ]} + \text{vps\_max\_latency\_increase\_plus1[ i ]} - 1 \qquad (7\text{-}2)$$

When vps_max_latency_increase_plus1[ i ] is equal to 0, no corresponding limit is expressed.

The value of vps_max_latency_increase_plus1[ i ] shall be in the range of 0 to $2^{32} - 2$, inclusive. When vps_max_latency_increase_plus1[ i ] is not present for i in the range of 0 to vps_max_sub_layers_minus1 − 1, inclusive, due to vps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to vps_max_latency_increase_plus1[ vps_max_sub_layers_minus1 ].

**vps_max_layer_id** specifies the maximum allowed value of nuh_layer_id of all NAL units in the CVS.

**vps_num_layer_sets_minus1** plus 1 specifies the number of layer sets that are specified by the VPS. In bitstreams conforming to this version of this Specification, the value of vps_num_layer_sets_minus1 shall be equal to 0. Although the value of vps_num_layer_sets_minus1 is required to be equal to 0 in this version of this Specification, decoders shall allow other values of vps_num_layer_sets_minus1 in the range of 0 to 1023, inclusive, to appear in the syntax.

**layer_id_included_flag**[ i ][ j ] equal to 1 specifies that the value of nuh_layer_id equal to j is included in the layer identifier list layerSetLayerIdList[ i ]. layer_id_included_flag[ i ][ j ] equal to 0 specifies that the value of nuh_layer_id equal to j is not included in the layer identifier list layerSetLayerIdList[ i ].

The value of numLayersInIdList[ 0 ] is set equal to 1 and the value of layerSetLayerIdList[ 0 ][ 0 ] is set equal to 0.

For each value of i in the range of 1 to vps_num_layer_sets_minus1, inclusive, the variable numLayersInIdList[ i ] and the layer identifier list layerSetLayerIdList[ i ] are derived as follows:

```
n = 0
for( m = 0; m  <=  vps_max_layer_id; m++ )
    if( layer_id_included_flag[ i ][ m ] )                                    (7-3)
        layerSetLayerIdList[ i ][ n++ ] = m
numLayersInIdList[ i ] = n
```

For each value of i in the range of 1 to vps_num_layer_sets_minus1, inclusive, numLayersInIdList[ i ] shall be in the range of 1 to vps_max_layers_minus1 + 1, inclusive.

When numLayersInIdList[ iA ] is equal to numLayersInIdList[ iB ] for any iA and iB in the range of 0 to vps_num_layer_sets_minus1, inclusive, with iA not equal to iB, the value of layerSetLayerIdList[ iA ][ n ] shall not be equal to layerSetLayerIdList[ iB ][ n ] for at least one value of n in the range of 0 to numLayersInIdList[ iA ], inclusive.

A layer set is identified by the associated layer identifier list. The i-th layer set specified by the VPS is associated with the layer identifier list layerSetLayerIdList[ i ], for i in the range of 0 to vps_num_layer_sets_minus1, inclusive.

A layer set consists of all operation points that are associated with the same layer identifier list.

Each operation point is identified by the associated layer identifier list, denoted as OpLayerIdList, which consists of the list of nuh_layer_id values of all NAL units included in the operation point, in increasing order of nuh_layer_id values, and a variable OpTid, which is equal to the highest TemporalId of all NAL units included in the operation point. The bitstream subset associated with the operation point identified by OpLayerIdList and OpTid is the output of the sub-bitstream extraction process as specified in clause 10 with the bitstream, the target highest TemporalId equal to OpTid, and the target layer identifier list equal to OpLayerIdList as inputs. The OpLayerIdList and OpTid that identify an operation point are also referred to as the OpLayerIdList and OpTid associated with the operation point, respectively.

**vps_timing_info_present_flag** equal to 1 specifies that vps_num_units_in_tick, vps_time_scale, vps_poc_proportional_to_timing_flag, and vps_num_hrd_parameters are present in the VPS. vps_timing_info_present_flag equal to 0 specifies that vps_num_units_in_tick, vps_time_scale, vps_poc_proportional_to_timing_flag, and vps_num_hrd_parameters are not present in the VPS.

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

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

**vps_poc_proportional_to_timing_flag** equal to 1 indicates that the picture order count value for each picture in the CVS that is not the first picture in the CVS, in decoding order, is proportional to the output time of the picture relative to the output time of the first picture in the CVS. vps_poc_proportional_to_timing_flag equal to 0 indicates that the picture order count value for each picture in the CVS that is not the first picture in the CVS, in decoding order, may or may not be proportional to the output time of the picture relative to the output time of the first picture in the CVS.

**vps_num_ticks_poc_diff_one_minus1** plus 1 specifies the number of clock ticks corresponding to a difference of picture order count values equal to 1. The value of vps_num_ticks_poc_diff_one_minus1 shall be in the range of 0 to $2^{32} - 2$, inclusive.

**vps_num_hrd_parameters** specifies the number of hrd_parameters( ) syntax structures present in the VPS RBSP. In bitstreams conforming to this version of this Specification, the value of vps_num_hrd_parameters shall be less than or equal to 1. Although the value of vps_num_hrd_parameters is required to be less than or equal to 1 in this version of this Specification, decoders shall allow other values of vps_num_hrd_parameters in the range of 0 to 1024, inclusive, to appear in the syntax.

**hrd_layer_set_idx**[ i ] specifies the index, into the list of layer sets specified by the VPS, of the layer set to which the i-th hrd_parameters( ) syntax structure in the VPS applies. In bitstreams conforming to this version of this Specification, the value of hrd_layer_set_idx[ i ] shall be equal to 0. Although the value of hrd_layer_set_idx[ i ] is required to be equal to 0 in this version of this Specification, decoders shall allow other values of hrd_layer_set_idx[ i ] in the range of 0 to 1023, inclusive, to appear in the syntax.

**cprms_present_flag**[ i ] equal to 1 specifies that the HRD parameters that are common for all sub-layers are present in the i-th hrd_parameters( ) syntax structure in the VPS. cprms_present_flag[ i ] equal to 0 specifies that the HRD parameters that are common for all sub-layers are not present in the i-th hrd_parameters( ) syntax structure in the VPS and are derived to be the same as the ( i − 1 )-th hrd_parameters( ) syntax structure in the VPS. cprms_present_flag[ 0 ] is inferred to be equal to 1.

**vps_extension_flag** equal to 0 specifies that no vps_extension_data_flag syntax elements are present in the VPS RBSP syntax structure. vps_extension_flag shall be equal to 0 in bitstreams conforming to this version of this Specification. The value of 1 for vps_extension_flag is reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore all data that follow the value 1 for vps_extension_flag in a VPS NAL unit.

**vps_extension_data_flag** may have any value. Its presence and value do not affect decoder conformance to profiles specified in this version of this Specification. Decoders conforming to this version of this Specification shall ignore all vps_extension_data_flag syntax elements.

### 7.4.3.2 Sequence parameter set RBSP semantics

**sps_video_parameter_set_id** specifies the value of the vps_video_parameter_set_id of the active VPS.

**sps_max_sub_layers_minus1** plus 1 specifies the maximum number of temporal sub-layers that may be present in each CVS referring to the SPS. The value of sps_max_sub_layers_minus1 shall be in the range of 0 to 6, inclusive.

**sps_temporal_id_nesting_flag**, when sps_max_sub_layers_minus1 is greater than 0, specifies whether inter prediction is additionally restricted for CVSs referring to the SPS. When vps_temporal_id_nesting_flag is equal to 1, sps_temporal_id_nesting_flag shall be equal to 1. When sps_max_sub_layers_minus1 is equal to 0, sps_temporal_id_nesting_flag shall be equal to 1.

NOTE 1 – The syntax element sps_temporal_id_nesting_flag is used to indicate that temporal up-switching, i.e. switching from decoding up to any TemporalId tIdN to decoding up to any TemporalId tIdM that is greater than tIdN, is always possible in the CVS.

**sps_seq_parameter_set_id** provides an identifier for the SPS for reference by other syntax elements. The value of sps_seq_parameter_set_id shall be in the range of 0 to 15, inclusive.

**chroma_format_idc** specifies the chroma sampling relative to the luma sampling as specified in subclause 6.2. The value of chroma_format_idc shall be in the range of 0 to 3, inclusive.

**separate_colour_plane_flag** equal to 1 specifies that the three colour components of the 4:4:4 chroma format are coded separately. separate_colour_plane_flag equal to 0 specifies that the colour components are not coded separately. When separate_colour_plane_flag is not present, it is inferred to be equal to 0. When separate_colour_plane_flag is equal to 1, the coded picture consists of three separate components, each of which consists of coded samples of one colour plane (Y, Cb, or Cr) and uses the monochrome coding syntax. In this case, each colour plane is associated with a specific colour_plane_id value.

NOTE 2 – There is no dependency in decoding processes between the colour planes having different colour_plane_id values. For example, the decoding process of a monochrome picture with one value of colour_plane_id does not use any data from monochrome pictures having different values of colour_plane_id for inter prediction.

Depending on the value of separate_colour_plane_flag, the value of the variable ChromaArrayType is assigned as follows:

– If separate_colour_plane_flag is equal to 0, ChromaArrayType is set equal to chroma_format_idc.

– Otherwise (separate_colour_plane_flag is equal to 1), ChromaArrayType is set equal to 0.

**pic_width_in_luma_samples** specifies the width of each decoded picture in units of luma samples. pic_width_in_luma_samples shall not be equal to 0 and shall be an integer multiple of MinCbSizeY.

**pic_height_in_luma_samples** specifies the height of each decoded picture in units of luma samples. pic_height_in_luma_samples shall not be equal to 0 and shall be an integer multiple of MinCbSizeY.

**conformance_window_flag** equal to 1 indicates that the conformance cropping window offset parameters follow next in the SPS. conformance_window_flag equal to 0 indicates that the conformance cropping window offset parameters are not present.

**conf_win_left_offset**, **conf_win_right_offset**, **conf_win_top_offset**, and **conf_win_bottom_offset** specify the samples of the pictures in the CVS that are output from the decoding process, in terms of a rectangular region specified in picture coordinates for output. When conformance_window_flag is equal to 0, the values of conf_win_left_offset, conf_win_right_offset, conf_win_top_offset, and conf_win_bottom_offset are inferred to be equal to 0.

The conformance cropping window contains the luma samples with horizontal picture coordinates from SubWidthC * conf_win_left_offset to pic_width_in_luma_samples − ( SubWidthC * conf_win_right_offset + 1 ) and vertical picture coordinates from SubHeightC * conf_win_top_offset to pic_height_in_luma_samples − ( SubHeightC * conf_win_bottom_offset + 1 ), inclusive.

The value of SubWidthC * ( conf_win_left_offset + conf_win_right_offset ) shall be less than pic_width_in_luma_samples, and the value of SubHeightC * ( conf_win_top_offset + conf_win_bottom_offset ) shall be less than pic_height_in_luma_samples.

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

NOTE 3 – The conformance cropping window offset parameters are only applied at the output. All internal decoding processes are applied to the uncropped picture size.

**bit_depth_luma_minus8** specifies the bit depth of the samples of the luma array $\text{BitDepth}_Y$ and the value of the luma quantization parameter range offset $\text{QpBdOffset}_Y$ as follows:

$$\text{BitDepth}_Y = 8 + \text{bit\_depth\_luma\_minus8} \quad (7\text{-}4)$$

$$\text{QpBdOffset}_Y = 6 * \text{bit\_depth\_luma\_minus8} \quad (7\text{-}5)$$

bit_depth_luma_minus8 shall be in the range of 0 to 6, inclusive.

**bit_depth_chroma_minus8** specifies the bit depth of the samples of the chroma arrays $\text{BitDepth}_C$ and the value of the chroma quantization parameter range offset $\text{QpBdOffset}_C$ as follows:

$$\text{BitDepth}_C = 8 + \text{bit\_depth\_chroma\_minus8} \quad (7\text{-}6)$$

$$\text{QpBdOffset}_C = 6 * \text{bit\_depth\_chroma\_minus8} \quad (7\text{-}7)$$

bit_depth_chroma_minus8 shall be in the range of 0 to 6, inclusive.

**log2_max_pic_order_cnt_lsb_minus4** specifies the value of the variable MaxPicOrderCntLsb that is used in the decoding process for picture order count as follows:

$$\text{MaxPicOrderCntLsb} = 2^{(\text{ log2\_max\_pic\_order\_cnt\_lsb\_minus4} + 4\text{ })} \quad (7\text{-}8)$$

The value of log2_max_pic_order_cnt_lsb_minus4 shall be in the range of 0 to 12, inclusive.

**sps_sub_layer_ordering_info_present_flag** equal to 1 specifies that sps_max_dec_pic_buffering_minus1[ i ], sps_max_num_reorder_pics[ i ], and sps_max_latency_increase_plus1[ i ] are present for sps_max_sub_layers_minus1 + 1 sub-layers. sps_sub_layer_ordering_info_present_flag equal to 0 specifies that the values of sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ], sps_max_num_reorder_pics[ sps_max_sub_layers_minus1 ], and sps_max_latency_increase_plus1[ sps_max_sub_layers_minus1 ] apply to all sub-layers.

**sps_max_dec_pic_buffering_minus1**[ i ] plus 1 specifies the maximum required size of the decoded picture buffer for the CVS in units of picture storage buffers when HighestTid is equal to i. The value of sps_max_dec_pic_buffering_minus1[ i ] shall be in the range of 0 to MaxDpbSize − 1 (as specified in subclause A.4), inclusive. When i is greater than 0, sps_max_dec_pic_buffering_minus1[ i ] shall be greater than or equal to sps_max_dec_pic_buffering_minus1[ i − 1 ]. The value of sps_max_dec_pic_buffering_minus1[ i ] shall be less than or equal to vps_max_dec_pic_buffering_minus1[ i ] for each value of i. When sps_max_dec_pic_buffering_minus1[ i ] is not present for i in the range of 0 to sps_max_sub_layers_minus1 − 1, inclusive, due to sps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ].

**sps_max_num_reorder_pics**[ i ] indicates the maximum allowed number of pictures that can precede any picture in the CVS in decoding order and follow that picture in output order when HighestTid is equal to i. The value of sps_max_num_reorder_pics[ i ] shall be in the range of 0 to sps_max_dec_pic_buffering_minus1[ i ], inclusive. When i is greater than 0, sps_max_num_reorder_pics[ i ] shall be greater than or equal to sps_max_num_reorder_pics[ i − 1 ]. The value of sps_max_num_reorder_pics[ i ] shall be less than or equal to vps_max_num_reorder_pics[ i ] for each value of i. When sps_max_num_reorder_pics[ i ] is not present for i in the range of 0 to sps_max_sub_layers_minus1 − 1, inclusive, due to sps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to sps_max_num_reorder_pics[ sps_max_sub_layers_minus1 ].

**sps_max_latency_increase_plus1**[ i ] not equal to 0 is used to compute the value of SpsMaxLatencyPictures[ i ], which specifies the maximum number of pictures that can precede any picture in the CVS in output order and follow that picture in decoding order when HighestTid is equal to i.

When sps_max_latency_increase_plus1[ i ] is not equal to 0, the value of SpsMaxLatencyPictures[ i ] is specified as follows:

$$\text{SpsMaxLatencyPictures}[\,i\,] = \text{sps\_max\_num\_reorder\_pics}[\,i\,] + \text{sps\_max\_latency\_increase\_plus1}[\,i\,] - 1 \quad (7\text{-}9)$$

When sps_max_latency_increase_plus1[ i ] is equal to 0, no corresponding limit is expressed.

The value of sps_max_latency_increase_plus1[ i ] shall be in the range of 0 to $2^{32} - 2$, inclusive. When vps_max_latency_increase_plus1[ i ] is not equal to 0, the value of sps_max_latency_increase_plus1[ i ] shall not be equal to 0 and shall be less than or equal to vps_max_latency_increase_plus1[ i ] for each value of i. When sps_max_latency_increase_plus1[ i ] is not present for i in the range of 0 to sps_max_sub_layers_minus1 − 1, inclusive, due to sps_sub_layer_ordering_info_present_flag being equal to 0, it is inferred to be equal to sps_max_latency_increase_plus1[ sps_max_sub_layers_minus1 ].

**log2_min_luma_coding_block_size_minus3** plus 3 specifies the minimum size of a luma coding block.

**log2_diff_max_min_luma_coding_block_size** specifies the difference between the maximum and minimum luma coding block size.

The variables MinCbLog2SizeY, CtbLog2SizeY, MinCbSizeY, CtbSizeY, PicWidthInMinCbsY, PicWidthInCtbsY, PicHeightInMinCbsY, PicHeightInCtbsY, PicSizeInMinCbsY, PicSizeInCtbsY, PicSizeInSamplesY, PicWidthInSamplesC, and PicHeightInSamplesC are derived as follows:

$$\text{MinCbLog2SizeY} = \text{log2\_min\_luma\_coding\_block\_size\_minus3} + 3 \quad (7\text{-}10)$$

$$\text{CtbLog2SizeY} = \text{MinCbLog2SizeY} + \text{log2\_diff\_max\_min\_luma\_coding\_block\_size} \quad (7\text{-}11)$$

$$\text{MinCbSizeY} = 1 \ll \text{MinCbLog2SizeY} \quad (7\text{-}12)$$

$$\text{CtbSizeY} = 1 \ll \text{CtbLog2SizeY} \quad (7\text{-}13)$$

$$\text{PicWidthInMinCbsY} = \text{pic\_width\_in\_luma\_samples} \,/\, \text{MinCbSizeY} \quad (7\text{-}14)$$

$$\text{PicWidthInCtbsY} = \text{Ceil}(\ \text{pic\_width\_in\_luma\_samples} \div \text{CtbSizeY}\ ) \quad (7\text{-}15)$$

$$\text{PicHeightInMinCbsY} = \text{pic\_height\_in\_luma\_samples} \,/\, \text{MinCbSizeY} \quad (7\text{-}16)$$

$$\text{PicHeightInCtbsY} = \text{Ceil}(\ \text{pic\_height\_in\_luma\_samples} \div \text{CtbSizeY}\ ) \quad (7\text{-}17)$$

$$\text{PicSizeInMinCbsY} = \text{PicWidthInMinCbsY} * \text{PicHeightInMinCbsY} \quad (7\text{-}18)$$

$$\text{PicSizeInCtbsY} = \text{PicWidthInCtbsY} * \text{PicHeightInCtbsY} \quad (7\text{-}19)$$

$$\text{PicSizeInSamplesY} = \text{pic\_width\_in\_luma\_samples} * \text{pic\_height\_in\_luma\_samples} \quad (7\text{-}20)$$

PicWidthInSamplesC = pic_width_in_luma_samples / SubWidthC (7-21)

PicHeightInSamplesC = pic_height_in_luma_samples / SubHeightC (7-22)

The variables CtbWidthC and CtbHeightC, which specify the width and height, respectively, of the array for each chroma coding tree block, are derived as follows:

– If chroma_format_idc is equal to 0 (monochrome) or separate_colour_plane_flag is equal to 1, CtbWidthC and CtbHeightC are both equal to 0.
– Otherwise, CtbWidthC and CtbHeightC are derived as follows:

CtbWidthC = CtbSizeY / SubWidthC (7-23)

CtbHeightC = CtbSizeY / SubHeightC (7-24)

**log2_min_transform_block_size_minus2** plus 2 specifies the minimum transform block size.

The variable Log2MinTrafoSize is set equal to log2_min_transform_block_size_minus2 + 2. The bitstream shall not contain data that result in Log2MinTrafoSize greater than or equal to MinCbLog2SizeY.

**log2_diff_max_min_transform_block_size** specifies the difference between the maximum and minimum transform block size.

The variable Log2MaxTrafoSize is set equal to log2_min_transform_block_size_minus2 + 2 + log2_diff_max_min_transform_block_size.

The bitstream shall not contain data that result in Log2MaxTrafoSize greater than Min( CtbLog2SizeY, 5 ).

The array ScanOrder[ log2BlockSize ][ scanIdx ][ sPos ][ sComp ] specifies the mapping of the scan position sPos, ranging from 0 to ( 1 << log2BlockSize ) * ( 1 << log2BlockSize ) − 1, inclusive, to horizontal and vertical components of the scan-order matrix. The array index scanIdx equal to 0 specifies an up-right diagonal scan order, scanIdx equal to 1 specifies a horizontal scan order, and scanIdx equal to 2 specifies a vertical scan order. The array index sComp equal to 0 specifies the horizontal component and the array index sComp equal to 1 specifies the vertical component. The array ScanOrder is derived as follows:

For the variable log2BlockSize ranging from 0 to 3, inclusive, the scanning order array ScanOrder is derived as follows:

– The up-right diagonal scan order array initialization process as specified in subclause 6.5.3 is invoked with 1 << log2BlockSize as input, and the output is assigned to ScanOrder[ log2BlockSize ][ 0 ].
– The horizontal scan order array initialization process as specified in subclause 6.5.4 is invoked with 1 << log2BlockSize as input, and the output is assigned to ScanOrder[ log2BlockSize ][ 1 ].
– The vertical scan order array initialization process as specified in subclause 6.5.5 is invoked with 1 << log2BlockSize as input, and the output is assigned to ScanOrder[ log2BlockSize ][ 2 ].

**max_transform_hierarchy_depth_inter** specifies the maximum hierarchy depth for transform units of coding units coded in inter prediction mode. The value of max_transform_hierarchy_depth_inter shall be in the range of 0 to CtbLog2SizeY − Log2MinTrafoSize, inclusive.

**max_transform_hierarchy_depth_intra** specifies the maximum hierarchy depth for transform blocks of coding blocks coded in intra prediction mode. The value of max_transform_hierarchy_depth_intra shall be in the range of 0 to CtbLog2SizeY − Log2MinTrafoSize, inclusive.

**scaling_list_enabled_flag** equal to 1 specifies that a scaling list is used for the scaling process for transform coefficients. scaling_list_enabled_flag equal to 0 specifies that scaling list is not used for the scaling process for transform coefficients.

**sps_scaling_list_data_present_flag** equal to 1 specifies that scaling list data are present in the SPS. sps_scaling_list_data_present_flag equal to 0 specifies that scaling list data are not present in the SPS. When not present, the value of sps_scaling_list_data_present_flag is inferred to be equal to 0. When scaling_list_enabled_flag is equal to 1 and sps_scaling_list_data_present_flag is equal to 0, the default scaling list data are used to derive the array ScalingFactor as described in the scaling list data semantics specified in subclause 7.4.5.

**amp_enabled_flag** equal to 1 specifies that asymmetric motion partitions, i.e. PartMode equal to PART_2NxnU, PART_2NxnD, PART_nLx2N, or PART_nRx2N, may be used in coding tree blocks. amp_enabled_flag equal to 0 specifies that asymmetric motion partitions cannot be used in coding tree blocks.

**sample_adaptive_offset_enabled_flag** equal to 1 specifies that the sample adaptive offset process is applied to the reconstructed picture after the deblocking filter process. sample_adaptive_offset_enabled_flag equal to 0 specifies that the sample adaptive offset process is not applied to the reconstructed picture after the deblocking filter process.

**pcm_enabled_flag** equal to 0 specifies that PCM data are not present in the CVS.

NOTE 4 – When MinCbLog2SizeY is equal to 6, PCM data are not present in the CVS even when pcm_enabled_flag is equal to 1. The maximum size of coding block with pcm_enabled_flag equal to 1 is restricted to be less than or equal to Min( CtbLog2SizeY, 5 ). Encoders are encouraged to use an appropriate combination of log2_min_luma_coding_block_size_minus3, log2_min_pcm_luma_coding_block_size_minus3, and log2_diff_max_min_pcm_luma_coding_block_size values when sending PCM data in the CVS.

**pcm_sample_bit_depth_luma_minus1** specifies the number of bits used to represent each of PCM sample values of the luma component as follows:

$$\text{PcmBitDepth}_Y = \text{pcm\_sample\_bit\_depth\_luma\_minus1} + 1 \qquad (7\text{-}25)$$

The value of $\text{PcmBitDepth}_Y$ shall be less than or equal to the value of $\text{BitDepth}_Y$.

**pcm_sample_bit_depth_chroma_minus1** specifies the number of bits used to represent each of PCM sample values of the chroma components as follows:

$$\text{PcmBitDepth}_C = \text{pcm\_sample\_bit\_depth\_chroma\_minus1} + 1 \qquad (7\text{-}26)$$

The value of $\text{PcmBitDepth}_C$ shall be less than or equal to the value of $\text{BitDepth}_C$.

**log2_min_pcm_luma_coding_block_size_minus3** plus 3 specifies the minimum size of coding blocks with pcm_flag equal to 1.

The variable Log2MinIpcmCbSizeY is set equal to log2_min_pcm_luma_coding_block_size_minus3 + 3. The value of Log2MinIpcmCbSizeY shall be in the range of MinCbLog2SizeY to Min( CtbLog2SizeY, 5 ), inclusive.

**log2_diff_max_min_pcm_luma_coding_block_size** specifies the difference between the maximum and minimum size of coding blocks with pcm_flag equal to 1.

The variable Log2MaxIpcmCbSizeY is set equal to log2_diff_max_min_pcm_luma_coding_block_size + Log2MinIpcmCbSizeY. The value of Log2MaxIpcmCbSizeY shall be less than or equal to Min( CtbLog2SizeY, 5 ).

**pcm_loop_filter_disabled_flag** specifies whether the loop filter process is disabled on reconstructed samples in a coding unit with pcm_flag equal to 1 as follows:

– If pcm_loop_filter_disabled_flag is equal to 1, the deblocking filter and sample adaptive offset filter processes on the reconstructed samples in a coding unit with pcm_flag equal to 1 are disabled.
– Otherwise (pcm_loop_filter_disabled_flag value is equal to 0), the deblocking filter and sample adaptive offset filter processes on the reconstructed samples in a coding unit with pcm_flag equal to 1 are not disabled.

When pcm_loop_filter_disabled_flag is not present, it is inferred to be equal to 0.

**num_short_term_ref_pic_sets** specifies the number of short_term_ref_pic_set( ) syntax structures included in the SPS. The value of num_short_term_ref_pic_sets shall be in the range of 0 to 64, inclusive.

NOTE 5 – A decoder should allocate memory for a total number of num_short_term_ref_pic_sets + 1 short_term_ref_pic_set( ) syntax structures since there may be a short_term_ref_pic_set( ) syntax structure directly signalled in the slice headers of a current picture. A short_term_ref_pic_set( ) syntax structure directly signalled in the slice headers of a current picture has an index equal to num_short_term_ref_pic_sets.

**long_term_ref_pics_present_flag** equal to 0 specifies that no long-term reference picture is used for inter prediction of any coded picture in the CVS. long_term_ref_pics_present_flag equal to 1 specifies that long-term reference pictures may be used for inter prediction of one or more coded pictures in the CVS.

**num_long_term_ref_pics_sps** specifies the number of candidate long-term reference pictures that are specified in the SPS. The value of num_long_term_ref_pics_sps shall be in the range of 0 to 32, inclusive.

**lt_ref_pic_poc_lsb_sps**[ i ] specifies the picture order count modulo MaxPicOrderCntLsb of the i-th candidate long-term reference picture specified in the SPS. The number of bits used to represent lt_ref_pic_poc_lsb_sps[ i ] is equal to log2_max_pic_order_cnt_lsb_minus4 + 4.

**used_by_curr_pic_lt_sps_flag**[ i ] equal to 0 specifies that the i-th candidate long-term reference picture specified in the SPS is not used for reference by a picture that includes in its long-term RPS the i-th candidate long-term reference picture specified in the SPS.

**sps_temporal_mvp_enabled_flag** equal to 1 specifies that slice_temporal_mvp_enabled_flag is present in the slice headers of non-IDR pictures in the CVS. sps_temporal_mvp_enabled_flag equal to 0 specifies that slice_temporal_mvp_enabled_flag is not present in slice headers and that temporal motion vector predictors are not used in the CVS.

**strong_intra_smoothing_enabled_flag** equal to 1 specifies that bi-linear interpolation is conditionally used in the filtering process in the CVS as specified in subclause 8.4.4.2.3. strong_intra_smoothing_enabled_flag equal to 0 specifies that that the bi-linear interpolation is not used in the CVS.

**vui_parameters_present_flag** equal to 1 specifies that the vui_parameters( ) syntax structure as specified in Annex E is present. vui_parameters_present_flag equal to 0 specifies that the vui_parameters( ) syntax structure as specified in Annex E is not present.

**sps_extension_flag** equal to 0 specifies that no sps_extension_data_flag syntax elements are present in the SPS RBSP syntax structure. sps_extension_flag shall be equal to 0 in bitstreams conforming to this version of this Specification. The value of 1 for sps_extension_flag is reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore all sps_extension_data_flag syntax elements that follow the value 1 for sps_extension_flag in an SPS NAL unit.

**sps_extension_data_flag** may have any value. Its presence and value do not affect decoder conformance to profiles specified in this version of this Specification. Decoders conforming to this version of this Specification shall ignore all sps_extension_data_flag syntax elements.

#### 7.4.3.3 Picture parameter set RBSP semantics

**pps_pic_parameter_set_id** identifies the PPS for reference by other syntax elements. The value of pps_pic_parameter_set_id shall be in the range of 0 to 63, inclusive.

**pps_seq_parameter_set_id** specifies the value of sps_seq_parameter_set_id for the active SPS. The value of pps_seq_parameter_set_id shall be in the range of 0 to 15, inclusive.

**dependent_slice_segments_enabled_flag** equal to 1 specifies the presence of the syntax element dependent_slice_segment_flag in the slice segment headers for coded pictures referring to the PPS. dependent_slice_segments_enabled_flag equal to 0 specifies the absence of the syntax element dependent_slice_segment_flag in the slice segment headers for coded pictures referring to the PPS.

**output_flag_present_flag** equal to 1 indicates that the pic_output_flag syntax element is present in the associated slice headers. output_flag_present_flag equal to 0 indicates that the pic_output_flag syntax element is not present in the associated slice headers.

**num_extra_slice_header_bits** equal to 0 specifies that no extra slice header bits are present in the slice header RBSP for coded pictures referring to the PPS. num_extra_slice_header_bits shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for num_extra_slice_header_bits are reserved for future use by ITU-T | ISO/IEC. However, decoders shall allow num_extra_slice_header_bits to have any value.

**sign_data_hiding_enabled_flag** equal to 0 specifies that sign bit hiding is disabled. sign_data_hiding_enabled_flag equal to 1 specifies that sign bit hiding is enabled.

**cabac_init_present_flag** equal to 1 specifies that cabac_init_flag is present in slice headers referring to the PPS. cabac_init_present_flag equal to 0 specifies that cabac_init_flag is not present in slice headers referring to the PPS.

**num_ref_idx_l0_default_active_minus1** specifies the inferred value of num_ref_idx_l0_active_minus1 for P and B slices with num_ref_idx_active_override_flag equal to 0. The value of num_ref_idx_l0_default_active_minus1 shall be in the range of 0 to 14, inclusive.

**num_ref_idx_l1_default_active_minus1** specifies the inferred value of num_ref_idx_l1_active_minus1 with num_ref_idx_active_override_flag equal to 0. The value of num_ref_idx_l1_default_active_minus1 shall be in the range of 0 to 14, inclusive.

**init_qp_minus26** specifies the initial value minus 26 of $\text{SliceQp}_Y$ for each slice. The initial value is modified at the slice segment layer when a non-zero value of slice_qp_delta is decoded, and is modified further when a non-zero value of cu_qp_delta_abs is decoded at the coding unit layer. The value of init_qp_minus26 shall be in the range of $-( 26 + \text{QpBdOffset}_Y )$ to +25, inclusive.

**constrained_intra_pred_flag** equal to 0 specifies that intra prediction allows usage of residual data and decoded samples of neighbouring coding blocks coded using either intra or inter prediction modes. constrained_intra_pred_flag equal to 1 specifies constrained intra prediction, in which case intra prediction only uses residual data and decoded samples from neighbouring coding blocks coded using intra prediction modes.

**transform_skip_enabled_flag** equal to 1 specifies that transform_skip_flag may be present in the residual coding syntax. transform_skip_enabled_flag equal to 0 specifies that transform_skip_flag is not present in the residual coding syntax.

**cu_qp_delta_enabled_flag** equal to 1 specifies that the diff_cu_qp_delta_depth syntax element is present in the PPS and that cu_qp_delta_abs may be present in the transform unit syntax. cu_qp_delta_enabled_flag equal to 0 specifies that the diff_cu_qp_delta_depth syntax element is not present in the PPS and that cu_qp_delta_abs is not present in the transform unit syntax.

**diff_cu_qp_delta_depth** specifies the difference between the luma coding tree block size and the minimum luma coding block size of coding units that convey cu_qp_delta_abs and cu_qp_delta_sign_flag. The value of diff_cu_qp_delta_depth shall be in the range of 0 to log2_diff_max_min_luma_coding_block_size, inclusive. When not present, the value of diff_cu_qp_delta_depth is inferred to be equal to 0.

The variable Log2MinCuQpDeltaSize is devived as follows:

$$\text{Log2MinCuQpDeltaSize} = \text{CtbLog2SizeY} - \text{diff\_cu\_qp\_delta\_depth} \qquad (7\text{-}27)$$

**pps_cb_qp_offset** and **pps_cr_qp_offset** specify offsets to the luma quantization parameter $Qp'_Y$ used for deriving $Qp'_{Cb}$ and $Qp'_{Cr}$, respectively. The values of pps_cb_qp_offset and pps_cr_qp_offset shall be in the range of −12 to +12, inclusive.

**pps_slice_chroma_qp_offsets_present_flag** equal to 1 indicates that the slice_cb_qp_offset and slice_cr_qp_offset syntax elements are present in the associated slice headers. pps_slice_chroma_qp_offsets_present_flag equal to 0 indicates that these syntax elements are not present in the associated slice headers.

**weighted_pred_flag** equal to 0 specifies that weighted prediction is not applied to P slices. weighted_pred_flag equal to 1 specifies that weighted prediction is applied to P slices.

**weighted_bipred_flag** equal to 0 specifies that the default weighted prediction is applied to B slices. weighted_bipred_flag equal to 1 specifies that weighted prediction is applied to B slices.

**transquant_bypass_enabled_flag** equal to 1 specifies that cu_transquant_bypass_flag is present. transquant_bypass_enabled_flag equal to 0 specifies that cu_transquant_bypass_flag is not present.

**tiles_enabled_flag** equal to 1 specifies that there is more than one tile in each picture referring to the PPS. tiles_enabled_flag equal to 0 specifies that there is only one tile in each picture referring to the PPS.

It is a requirement of bitstream conformance that the value of tiles_enabled_flag shall be the same for all PPSs that are activated within a CVS.

**entropy_coding_sync_enabled_flag** equal to 1 specifies that a specific synchronization process for context variables is invoked before decoding the coding tree unit which includes the first coding tree block of a row of coding tree blocks in each tile in each picture referring to the PPS, and a specific storage process for context variables is invoked after decoding the coding tree unit which includes the second coding tree block of a row of coding tree blocks in each tile in each picture referring to the PPS. entropy_coding_sync_enabled_flag equal to 0 specifies that no specific synchronization process for context variables is required to be invoked before decoding the coding tree unit which includes the first coding tree block of a row of coding tree blocks in each tile in each picture referring to the PPS, and no specific storage process for context variables is required to be invoked after decoding the coding tree unit which includes the second coding tree block of a row of coding tree blocks in each tile in each picture referring to the PPS.

It is a requirement of bitstream conformance that the value of entropy_coding_sync_enabled_flag shall be the same for all PPSs that are activated within a CVS.

When entropy_coding_sync_enabled_flag is equal to 1 and the first coding tree block in a slice is not the first coding tree block of a row of coding tree blocks in a tile, it is a requirement of bitstream conformance that the last coding tree block in the slice shall belong to the same row of coding tree blocks as the first coding tree block in the slice.

When entropy_coding_sync_enabled_flag is equal to 1 and the first coding tree block in a slice segment is not the first coding tree block of a row of coding tree blocks in a tile, it is a requirement of bitstream conformance that the last coding tree block in the slice segment shall belong to the same row of coding tree blocks as the first coding tree block in the slice segment.

**num_tile_columns_minus1** plus 1 specifies the number of tile columns partitioning the picture. num_tile_columns_minus1 shall be in the range of 0 to PicWidthInCtbsY − 1, inclusive. When not present, the value of num_tile_columns_minus1 is inferred to be equal to 0.

**num_tile_rows_minus1** plus 1 specifies the number of tile rows partitioning the picture. num_tile_rows_minus1 shall be in the range of 0 to PicHeightInCtbsY − 1, inclusive. When not present, the value of num_tile_rows_minus1 is inferred to be equal to 0.

When tiles_enabled_flag is equal to 1, num_tile_columns_minus1 and num_tile_rows_minus1 shall not be both equal to 0.

**uniform_spacing_flag** equal to 1 specifies that tile column boundaries and likewise tile row boundaries are distributed uniformly across the picture. uniform_spacing_flag equal to 0 specifies that tile column boundaries and likewise tile row boundaries are not distributed uniformly across the picture but signalled explicitly using the syntax elements column_width_minus1[ i ] and row_height_minus1[ i ]. When not present, the value of uniform_spacing_flag is inferred to be equal to 1.

**column_width_minus1**[ i ] plus 1 specifies the width of the i-th tile column in units of coding tree blocks.

**row_height_minus1**[ i ] plus 1 specifies the height of the i-th tile row in units of coding tree blocks.

The following variables are derived by invoking the coding tree block raster and tile scanning conversion process as specified in subclause 6.5.1:

– The list CtbAddrRsToTs[ ctbAddrRs ] for ctbAddrRs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in CTB raster scan of a picture to a CTB address in tile scan,

– the list CtbAddrTsToRs[ ctbAddrTs ] for ctbAddrTs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in tile scan to a CTB address in CTB raster scan of a picture,

– the list TileId[ ctbAddrTs ] for ctbAddrTs ranging from 0 to PicSizeInCtbsY − 1, inclusive, specifying the conversion from a CTB address in tile scan to a tile ID,

– the list ColumnWidthInLumaSamples[ i ] for i ranging from 0 to num_tile_columns_minus1, inclusive, specifying the width of the i-th tile column in units of luma samples,

– the list RowHeightInLumaSamples[ j ] for j ranging from 0 to num_tile_rows_minus1, inclusive, specifying the height of the j-th tile row in units of luma samples.

The values of ColumnWidthInLumaSamples[ i ] for i ranging from 0 to num_tile_columns_minus1, inclusive, and RowHeightInLumaSamples[ j ] for j ranging from 0 to num_tile_rows_minus1, inclusive, shall all be greater than 0.

The array MinTbAddrZs with elements MinTbAddrZs[ x ][ y ] for x ranging from 0 to ( PicWidthInCtbsY << ( CtbLog2SizeY − Log2MinTrafoSize ) ) − 1, inclusive, and y ranging from 0 to ( PicHeightInCtbsY << ( CtbLog2SizeY − Log2MinTrafoSize ) ) − 1, inclusive, specifying the conversion from a location ( x, y ) in units of minimum transform blocks to a transform block address in z-scan order, is derived by invoking the z-scan order array initialization process as specified in subclause 6.5.2.

**loop_filter_across_tiles_enabled_flag** equal to 1 specifies that in-loop filtering operations may be performed across tile boundaries in pictures referring to the PPS. loop_filter_across_tiles_enabled_flag equal to 0 specifies that in-loop filtering operations are not performed across tile boundaries in pictures referring to the PPS. The in-loop filtering operations include the deblocking filter and sample adaptive offset filter operations. When not present, the value of loop_filter_across_tiles_enabled_flag is inferred to be equal to 1.

**pps_loop_filter_across_slices_enabled_flag** equal to 1 specifies that in-loop filtering operations may be performed across left and upper boundaries of slices referring to the PPS. pps_loop_filter_across_slices_enabled_flag equal to 0 specifies that in-loop filtering operations are not performed across left and upper boundaries of slices referring to the PPS. The in-loop filtering operations include the deblocking filter and sample adaptive offset filter operations.

NOTE 1 – Loop filtering across slice boundaries can be enabled while loop filtering across tile boundaries is disabled and vice versa.

**deblocking_filter_control_present_flag** equal to 1 specifies the presence of deblocking filter control syntax elements in the PPS. deblocking_filter_control_present_flag equal to 0 specifies the absence of deblocking filter control syntax elements in the PPS.

**deblocking_filter_override_enabled_flag** equal to 1 specifies the presence of deblocking_filter_override_flag in the slice headers for pictures referring to the PPS. deblocking_filter_override_enabled_flag equal to 0 specifies the absence of deblocking_filter_override_flag in the slice headers for pictures referring to the PPS. When not present, the value of deblocking_filter_override_enabled_flag is inferred to be equal to 0.

**pps_deblocking_filter_disabled_flag** equal to 1 specifies that the operation of deblocking filter is not applied for slices referring to the PPS in which slice_deblocking_filter_disabled_flag is not present. pps_deblocking_filter_disabled_flag equal to 0 specifies that the operation of the deblocking filter is applied for slices referring to the PPS in which slice_deblocking_filter_disabled_flag is not present. When not present, the value of pps_deblocking_filter_disabled_flag is inferred to be equal to 0.

**pps_beta_offset_div2** and **pps_tc_offset_div2** specify the default deblocking parameter offsets for β and tC (divided by 2) that are applied for slices referring to the PPS, unless the default deblocking parameter offsets are overridden by the deblocking parameter offsets present in the slice headers of the slices referring to the PPS. The values of pps_beta_offset_div2 and pps_tc_offset_div2 shall both be in the range of −6 to 6, inclusive. When not present, the value of pps_beta_offset_div2 and pps_tc_offset_div2 are inferred to be equal to 0.

**pps_scaling_list_data_present_flag** equal to 1 specifies that parameters are present in the PPS to modify the scaling lists specified in the active SPS. pps_scaling_list_data_present_flag equal to 0 specifies that the scaling lists used for the pictures referring to the PPS is inferred to be equal to those specified by the active SPS. When scaling_list_enabled_flag is equal to 0, the value of pps_scaling_list_data_present_flag shall be equal to 0. When scaling_list_enabled_flag is equal to 1, sps_scaling_list_data_present_flag is equal to 0, and pps_scaling_list_data_present_flag is equal to 0, the default scaling list data are used to derive the array ScalingFactor as described in the scaling list data semantics 7.4.5.

**lists_modification_present_flag** equal to 1 specifies that the syntax structure ref_pic_lists_modification( ) is present in the slice segment header. lists_modification_present_flag equal to 0 specifies that the syntax structure ref_pic_lists_modification( ) is not present in the slice segment header.

**log2_parallel_merge_level_minus2** plus 2 specifies the value of the variable Log2ParMrgLevel, which is used in the derivation process for luma motion vectors for merge mode as specified in subclause 8.5.3.2.1 and the derivation process for spatial merging candidates as specified in subclause 8.5.3.2.2. The value of log2_parallel_merge_level_minus2 shall be in the range of 0 to CtbLog2SizeY − 2, inclusive.

The variable Log2ParMrgLevel is derived as follows:

$$\text{Log2ParMrgLevel} = \text{log2\_parallel\_merge\_level\_minus2} + 2 \quad (7\text{-}28)$$

NOTE 2 – The value of Log2ParMrgLevel indicates the built-in capability of parallel derivation of the merging candidate lists. For example, when Log2ParMrgLevel is equal to 6, the merging candidate lists for all the PUs and CUs contained in a 64x64 block can be derived in parallel.

**slice_segment_header_extension_present_flag** equal to 0 specifies that no slice segment header extension syntax elements are present in the slice segment headers for coded pictures referring to the PPS. slice_segment_header_extension_present_flag shall be equal to 0 in bitstreams conforming to this version of this Specification. The value of 1 for slice_segment_header_extension_present_flag is reserved for future use by ITU-T | ISO/IEC.

**pps_extension_flag** equal to 0 specifies that no pps_extension_data_flag syntax elements are present in the PPS RBSP syntax structure. pps_extension_flag shall be equal to 0 in bitstreams conforming to this version of this Specification. The value of 1 for pps_extension_flag is reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore all data that follow the value 1 for pps_extension_flag in a PPS NAL unit.

**pps_extension_data_flag** may have any value. Its presence and value do not affect decoder conformance to profiles specified in this version of this Specification. Decoders conforming to this version of this Specification shall ignore all pps_extension_data_flag syntax elements.

#### 7.4.3.4 Supplemental enhancement information RBSP semantics

Supplemental Enhancement Information (SEI) contains information that is not necessary to decode the samples of coded pictures from VCL NAL units. An SEI RBSP contains one or more SEI messages.

#### 7.4.3.5 Access unit delimiter RBSP semantics

The access unit delimiter may be used to indicate the type of slices present in a coded picture and to simplify the detection of the boundary between access units. There is no normative decoding process associated with the access unit delimiter.

**pic_type** indicates that the slice_type values for all slices of the coded picture are members of the set listed in Table 7-2 for the given value of pic_type.

**Table 7-2 – Interpretation of pic_type**

| pic_type | slice_type values that may be present in the coded picture |
|---|---|
| 0 | I |
| 1 | P, I |
| 2 | B, P, I |

#### 7.4.3.6 End of sequence RBSP semantics

The end of sequence RBSP specifies that the current access unit is the last access unit in the coded video sequence in decoding order and the next subsequent access unit in the bitstream in decoding order (if any) is an IRAP access unit with NoRaslOutputFlag equal to 1. The syntax content of the SODB and RBSP for the end of sequence RBSP are empty.

#### 7.4.3.7 End of bitstream RBSP semantics

The end of bitstream RBSP indicates that no additional NAL units are present in the bitstream that are subsequent to the end of bitstream RBSP in decoding order. The syntax content of the SODB and RBSP for the end of bitstream RBSP are empty.

NOTE – When an elementary stream contains more than one bitstream, the last NAL unit of the last access unit of a bitstream must contain an end of bitstream NAL unit and the first access unit of the subsequent bitstream must be an IRAP access unit. This IRAP access unit may be a CRA, BLA, or IDR access unit.

### 7.4.3.8 Filler data RBSP semantics

The filler data RBSP contains bytes whose value shall be equal to 0xFF. No normative decoding process is specified for a filler data RBSP.

**ff_byte** is a byte equal to 0xFF.

### 7.4.3.9 Slice segment layer RBSP semantics

The slice segment layer RBSP consists of a slice segment header and slice segment data.

### 7.4.3.10 RBSP slice segment trailing bits semantics

**cabac_zero_word** is a byte-aligned sequence of two bytes equal to 0x0000.

Let NumBytesInVclNalUnits be the sum of the values of NumBytesInNalUnit for all VCL NAL units of a coded picture.

Let BinCountsInNalUnits be the number of times that the parsing process function DecodeBin( ), specified in subclause 9.3.4.3, is invoked to decode the contents of all VCL NAL units of a coded picture.

Let the variable RawMinCuBits be derived as follows:

$$\text{RawMinCuBits} = \text{MinCbSizeY} * \text{MinCbSizeY} * (\text{BitDepth}_Y + \text{BitDepth}_C / 2) \quad (7\text{-}29)$$

The value of BinCountsInNalUnits shall be less than or equal to ( 32 ÷ 3 ) * NumBytesInVclNalUnits + ( RawMinCuBits * PicSizeInMinCbsY ) ÷ 32.

NOTE – The constraint on the maximum number of bins resulting from decoding the contents of the coded slice segment NAL units can be met by inserting a number of cabac_zero_word syntax elements to increase the value of NumBytesInVclNalUnits. Each cabac_zero_word is represented in a NAL unit by the three-byte sequence 0x000003 (as a result of the constraints on NAL unit contents that result in requiring inclusion of an emulation_prevention_three_byte for each cabac_zero_word).

### 7.4.3.11 RBSP trailing bits semantics

**rbsp_stop_one_bit** shall be equal to 1.

**rbsp_alignment_zero_bit** shall be equal to 0.

### 7.4.3.12 Byte alignment semantics

**alignment_bit_equal_to_one** shall be equal to 1.

**alignment_bit_equal_to_zero** shall be equal to 0.

## 7.4.4 Profile, tier and level semantics

**general_profile_space** specifies the context for the interpretation of general_profile_idc and general_profile_combatibility_flag[ i ] for all values of i in the range of 0 to 31, inclusive. The value of general_profile_space shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for general_profile_space are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the CVS when general_profile_space is not equal to 0.

**general_tier_flag** specifies the tier context for the interpretation of general_level_idc as specified in Annex A.

**general_profile_idc**, when general_profile_space is equal to 0, indicates a profile to which the CVS conforms as specified in Annex A. Bitstreams shall not contain values of general_profile_idc other than those specified in Annex A. Other values of general_profile_idc are reserved for future use by ITU-T | ISO/IEC.

**general_profile_compatibility_flag**[ j ] equal to 1, when general_profile_space is equal to 0, indicates that the CVS conforms to the profile indicated by general_profile_idc equal to i as specified in Annex A. When general_profile_space is equal to 0, general_profile_compatibility_flag[ general_profile_idc ] shall be equal to 1. The value of general_profile_compatibility_flag[ j ] shall be equal to 0 for any value of j that is not specified as an allowed value of general_profile_idc in Annex A.

**general_progressive_source_flag** and **general_interlaced_source_flag** are interpreted as follows:

– If general_progressive_source_flag is equal to 1 and general interlaced_source_flag is equal to 0, the source scan type of the pictures in the CVS should be interpreted as progressive only.

– Otherwise, if general_progressive_source_flag is equal to 0 and general_interlaced_source_flag is equal to 1, the source scan type of the pictures in the CVS should be interpreted as interlaced only.

– Otherwise, if general_progressive_source_flag is equal to 0 and general_interlaced_source_flag is equal to 0, the source scan type of the pictures in the CVS should be interpreted as unknown or unspecified.

– Otherwise (general_progressive_source_flag is equal to 1 and general_interlaced_source_flag is equal to 1), the source scan type of each picture in the CVS is indicated at the picture level using the syntax element source_scan_type in a picture timing SEI message.

NOTE 1 – Decoders may ignore the values of general_progressive_source_flag and general_interlaced_source_flag for purposes other than determining the value to be inferred for frame_field_info_present_flag when vui_params_present_flag is equal to 0, as there are no other decoding process requirements associated with the values of these flags. Moreover, the actual source scan type of the pictures is outside the scope of this Specification, and the method by which the encoder selects the values of general_progressive_source_flag and general_interlaced_source_flag is unspecified.

**general_non_packed_constraint_flag** equal to 1 specifies that there are no frame packing arrangement SEI messages present in the CVS. general non_packed_constraint_flag equal to 0 indicates that there may or may not be one or more frame packing arrangement SEI messages present in the CVS.

NOTE 2 – Decoders may ignore the value of general_non_packed_constraint_flag, as there are no decoding process requirements associated with the presence or interpretation of frame packing arrangement SEI messages.

**general_frame_only_constraint_flag** equal to 1 specifies that field_seq_flag is equal to 0. general_frame_only_constraint_flag equal to 0 indicates that field_seq_flag may or may not be equal to 0.

NOTE 3 – Decoders may ignore the value of general_frame_only_constraint_flag, as there are no decoding process requirements associated with the value of field_seq_flag.

NOTE 4 – When general_progressive_source_flag is equal to 1, general_frame_only_constraint_flag may or may not be equal to 1.

**general_reserved_zero_44bits** shall be equal to 0 in bitstreams conforming to this version of this Specification. Other values for general_reserved_zero_44bits are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the value of general_reserved_zero_44bits.

**general_level_idc** indicates a level to which the CVS conforms as specified in Annex A. Bitstreams shall not contain values of general_level_idc other than those specified in Annex A. Other values of general_level_idc are reserved for future use by ITU-T | ISO/IEC.

NOTE 5 – A greater value of general_level_idc indicates a higher level. The maximum level signalled in the VPS for a CVS may be higher than the level signalled in the SPS for the same CVS.

NOTE 6 – When the coded video sequence conforms to multiple profiles, general_profile_idc should indicate the profile that provides the preferred decoded result or the preferred bitstream identification, as determined by the encoder (in a manner not specified in this Specification).

NOTE 7 – The general_reserved_zero_44bits may be used in future editions of this Specification to indicate further constraints on the bitstream (e.g. that a particular syntax combination that would otherwise be permitted by the indicated values of general_profile_compatibility_flag[ j ], is not used).

**sub_layer_profile_present_flag**[ i ] equal to 1, specifies that profile information is present in the profile_tier_level( ) syntax structure for the representation of the sub-layer with TemporalId equal to i. sub_layer_profile_present_flag[ i ] equal to 0 specifies that profile information is not present in the profile_tier_level( ) syntax structure for the representations of the sub-layer with TemporalId equal to i.

**sub_layer_level_present_flag**[ i ] equal to 1 specifies that level information is present in the profile_tier_level( ) syntax structure for the representation of the sub-layer with TemporalId equal to i. sub_layer_level_present_flag[ i ] equal to 0 specifies that level information is not present in the profile_tier_level( ) syntax structure for the representation of the sub-layer with TemporalId equal to i.

**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 ].

The semantics of the syntax elements **sub_layer_profile_space**[ i ], **sub_layer_tier_flag**[ i ], **sub_layer_profile_idc**[ i ], **sub_layer_profile_compatibility_flag**[ i ][ j ], **sub_layer_progressive_source_flag**[ i ], **sub_layer_interlaced_source_flag**[ i ], **sub_layer_non_packed_constraint_flag**[ i ], **sub_layer_frame_only_constraint_flag**[ i ], **sub_layer_reserved_zero_44bits**[ i ], and **sub_layer_level_idc**[ i ] are the same as the syntax elements general_profile_space, general_tier_flag, general_profile_idc, general_profile_compatibility_flag[ j ], general_progressive_source_flag, general_interlaced_source_flag, general_non_packed_constraint_flag, general_frame_only_constraint_flag, general_reserved_zero_44bits, and general_level_idc, respectively, but apply to the representation of the sub-layer with TemporalId equal to i.

When not present, the value of sub_layer_tier_flag[ i ] is inferred to be equal to 0.

NOTE 8 – It is possible that sub_layer_tier_flag[ i ] is not present and sub_layer_level_idc[ i ] is present. In this case, a default value of sub_layer_tier_flag[ i ] is needed for interpretation of sub_layer_level_idc[ i ].

### 7.4.5 Scaling list data semantics

**scaling_list_pred_mode_flag**[ sizeId ][ matrixId ] equal to 0 specifies that the values of the scaling list are the same as the values of a reference scaling list. The reference scaling list is specified by scaling_list_pred_matrix_id_delta[ sizeId ][ matrixId ]. scaling_list_pred_mode_flag[ sizeId ][ matrixId ] equal to 1 specifies that the values of the scaling list are explicitly signalled.

**scaling_list_pred_matrix_id_delta**[ sizeId ][ matrixId ] specifies the reference scaling list used to derive ScalingList[ sizeId ][ matrixId ] as follows:

– If scaling_list_pred_matrix_id_delta is equal to 0, the scaling list is inferred from the default scaling list ScalingList[ sizeId ][ matrixId ][ i ] as specified in Table 7-5 and Table 7-6 for i = 0..Min( 64, ( 1 << ( 4 + ( sizeId << 1 ) ) ) ).
– Otherwise, the scaling list is inferred from the reference scaling list as follows:

refMatrixId = matrixId − scaling_list_pred_matrix_id_delta[ sizeId ][ matrixId ] (7-30)

ScalingList[ sizeId ][ matrixId ][ i ] = ScalingList[ sizeId ][ refMatrixId ][ i ]
with i =0..Min( 64, ( 1 << ( 4 + ( sizeId << 1 ) ) ) ) (7-31)

The value of scaling_list_pred_matrix_id_delta[ sizeId ][ matrixId ] shall be in the range of 0 to matrixId, inclusive.

**Table 7-3 – Specification of sizeId**

| Size of quantization matrix | sizeId |
|---|---|
| 4x4 | 0 |
| 8x8 | 1 |
| 16x16 | 2 |
| 32x32 | 3 |

**Table 7-4 – Specification of matrixId according to sizeId, prediction mode and colour component**

| sizeId | CuPredMode | cIdx (colour component) | matrixId |
|---|---|---|---|
| 0, 1, 2 | MODE_INTRA | 0 (Y) | 0 |
| 0, 1, 2 | MODE_INTRA | 1 (Cb) | 1 |
| 0, 1, 2 | MODE_INTRA | 2 (Cr) | 2 |
| 0, 1, 2 | MODE_INTER | 0 (Y) | 3 |
| 0, 1, 2 | MODE_INTER | 1 (Cb) | 4 |
| 0, 1, 2 | MODE_INTER | 2 (Cr) | 5 |
| 3 | MODE_INTRA | 0 (Y) | 0 |
| 3 | MODE_INTER | 0 (Y) | 1 |

**scaling_list_dc_coef_minus8**[ sizeId − 2 ][ matrixId ] plus 8 specifies the DC value of the scaling list for 16x16 size when sizeId is equal to 2 and specifies the DC value of the scaling list for 32x32 size when sizeId is equal to 3. The value of scaling_list_dc_coef_minus8[ sizeId − 2 ][ matrixId ] shall be in the range of −7 to 247, inclusive. When scaling_list_dc_coef_minus8 is not present, it is inferred to be equal to 8.

**scaling_list_delta_coef** specifies the difference between the current matrix coefficient ScalingList[ sizeId ][ matrixId ][ i ] and the previous matrix coefficient ScalingList[ sizeId ][ matrixId ][ i − 1 ], when scaling_list_pred_mode_flag[ sizeId ][ matrixId ] is equal to 1. The value of scaling_list_delta_coef shall be in the range of −128 to 127, inclusive. The value of ScalingList[ sizeId ][ matrixId ][ i ] shall be greater than 0.

**Table 7-5 – Specification of default values of ScalingList[ 0 ][ matrixId ][ i ] with i = 0..15**

| i | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ScalingList[ 0 ][ 0..5 ][ i ] | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 |

**Table 7-6 – Specification of default values of ScalingList[ 1..3 ][ matrixId ][ i ] with i = 0..63**

| **i** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ScalingList[ 1..2 ][ 0..2 ][ i ]**<br>**ScalingList[ 3 ][ 0 ][ i ]** | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 17 | 16 | 17 | 16 | 17 | 18 |
| **ScalingList[ 1..2 ][ 3..5 ][ i ]**<br>**ScalingList[ 3 ][ 1 ][ i ]** | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 16 | 17 | 17 | 17 | 17 | 17 | 18 |
| **i − 16** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **ScalingList[ 1..2 ][ 0..2 ][ i ]**<br>**ScalingList[ 3 ][ 0 ][ i ]** | 17 | 18 | 18 | 17 | 18 | 21 | 19 | 20 | 21 | 20 | 19 | 21 | 24 | 22 | 22 | 24 |
| **ScalingList[ 1..2 ][ 3..5 ][ i ]**<br>**ScalingList[ 3 ][ 1 ][ i ]** | 18 | 18 | 18 | 18 | 18 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 24 | 24 | 24 | 24 |
| **i − 32** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **ScalingList[ 1..2 ][ 0..2 ][ i ]**<br>**ScalingList[ 3 ][ 0 ][ i ]** | 24 | 22 | 22 | 24 | 25 | 25 | 27 | 30 | 27 | 25 | 25 | 29 | 31 | 35 | 35 | 31 |
| **ScalingList[ 1..2 ][ 3..5 ][ i ]**<br>**ScalingList[ 3 ][ 1 ][ i ]** | 24 | 24 | 24 | 24 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 28 | 28 | 28 | 28 | 28 |
| **i − 48** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **ScalingList[ 1..2 ][ 0..2 ][ i ]**<br>**ScalingList[ 3 ][ 0 ][ i ]** | 29 | 36 | 41 | 44 | 41 | 36 | 47 | 54 | 54 | 47 | 65 | 70 | 65 | 88 | 88 | 115 |
| **ScalingList[ 1..2 ][ 3..5 ][ i ]**<br>**ScalingList[ 3 ][ 1 ][ i ]** | 28 | 33 | 33 | 33 | 33 | 33 | 41 | 41 | 41 | 41 | 54 | 54 | 54 | 71 | 71 | 91 |

The four-dimensional array ScalingFactor[ sizeId ][ matrixId ][ x ][ y ], with x, y = 0..( 1 << ( 2 + sizeId ) ) − 1, specifies the array of scaling factors according to the variables sizeId specified in Table 7-3 and matrixId specified in Table 7-4.

The elements of the quantization matrix of size 4x4, ScalingFactor[ 0 ][ matrixId ][ ][ ], are derived as follows:

ScalingFactor[ 0 ][ matrixId ][ x ][ y ] = ScalingList[ 0 ][ matrixId ][ i ] (7-32)
with i = 0..15, matrixId = 0..5, x = ScanOrder[ 2 ][ 0 ][ i ][ 0 ], and y = ScanOrder[ 2 ][ 0 ][ i ][ 1 ]

The elements of the quantization matrix of size 8x8, ScalingFactor[ 1 ][ matrixId ][ ][ ], are derived as follows:

ScalingFactor[ 1 ][ matrixId ][ x ][ y ] = ScalingList[ 1 ][ matrixId ][ i ] (7-33)
with i = 0..63, matrixId = 0..5, x = ScanOrder[ 3 ][ 0 ][ i ][ 0 ], and y = ScanOrder[ 3 ][ 0 ][ i ][ 1 ]

The elements of the quantization matrix of size 16x16, ScalingFactor[ 2 ][ matrixId ][ ][ ], are derived as follows:

ScalingFactor[ 2 ][ matrixId ][ x * 2 + k ][ y * 2 + j ] = ScalingList[ 2 ][ matrixId ][ i ] (7-34)
with i = 0..63, j = 0..1, k = 0..1, matrixId = 0..5, x = ScanOrder[ 3 ][ 0 ][ i ][ 0 ],
and y = ScanOrder[ 3 ][ 0 ][ i ][ 1 ]

ScalingFactor[ 2 ][ matrixId ][ 0 ][ 0 ] = scaling_list_dc_coef_minus8[ 0 ][ matrixId ] + 8 (7-35)
with matrixId = 0..5

The elements of the quantization matrix of size 32x32, ScalingFactor[ 3 ][ matrixId ][ ][ ], are derived as follows:

ScalingFactor[ 3 ][ matrixId ][ x * 4 + k ][ y * 4 + j ] = ScalingList[ 3 ][ matrixId ][ i ] (7-36)
with i = 0..63, j = 0..3, k = 0..3, matrixId = 0..1, x = ScanOrder[ 3 ][ 0 ][ i ][ 0 ],
and y = ScanOrder[ 3 ][ 0 ][ i ][ 1 ]

ScalingFactor[ 3 ][ matrixId ][ 0 ][ 0 ] = scaling_list_dc_coef_minus8[ 1 ][ matrixId ] + 8 (7-37)
with matrixId = 0..1

### 7.4.6 Supplemental enhancement information message semantics

Each SEI message consists of the variables specifying the type payloadType and size payloadSize of the SEI message payload. SEI message payloads are specified in Annex D. The derived SEI message payload size payloadSize is specified in bytes and shall be equal to the number of RBSP bytes in the SEI message payload.

NOTE – The NAL unit byte sequence containing the SEI message might include one or more emulation prevention bytes (represented by emulation_prevention_three_byte syntax elements). Since the payload size of an SEI message is specified in RBSP bytes, the quantity of emulation prevention bytes is not included in the size payloadSize of an SEI payload.

**ff_byte** is a byte equal to 0xFF identifying a need for a longer representation of the syntax structure that it is used within.

**last_payload_type_byte** is the last byte of the payload type of an SEI message.

**last_payload_size_byte** is the last byte of the payload size of an SEI message.

### 7.4.7 Slice segment header semantics

#### 7.4.7.1 General slice segment header semantics

When present, the value of the slice segment header syntax elements slice_pic_parameter_set_id, pic_output_flag, no_output_of_prior_pics_flag, slice_pic_order_cnt_lsb, short_term_ref_pic_set_sps_flag, short_term_ref_pic_set_idx, num_long_term_sps, num_long_term_pics, and slice_temporal_mvp_enabled_flag shall be the same in all slice segment headers of a coded picture. When present, the value of the slice segment header syntax elements lt_idx_sps[ i ], poc_lsb_lt[ i ], used_by_curr_pic_lt_flag[ i ], delta_poc_msb_present_flag[ i ], and delta_poc_msb_cycle_lt[ i ] shall be the same in all slice segment headers of a coded picture for each possible value of i.

**first_slice_segment_in_pic_flag** equal to 1 specifies that the slice segment is the first slice segment of the picture in decoding order. first_slice_segment_in_pic_flag equal to 0 specifies that the slice segment is not the first slice segment of the picture in decoding order.

**no_output_of_prior_pics_flag** affects the output of previously-decoded pictures in the decoded picture buffer after the decoding of an IDR or a BLA picture that is not the first picture in the bitstream as specified in Annex C.

**slice_pic_parameter_set_id** specifies the value of pps_pic_parameter_set for the PPS in use. The value of slice_pic_parameter_set_id shall be in the range of 0 to 63, inclusive.

**dependent_slice_segment_flag** equal to 1 specifies that the value of each slice segment header syntax element that is not present is inferred to be equal to the value of the corresponding slice segment header syntax element in the slice header. When not present, the value of dependent_slice_segment_flag is inferred to be equal to 0.

The variable SliceAddrRs is derived as follows:

– If dependent_slice_segment_flag is equal to 0, SliceAddrRs is set equal to slice_segment_address.

– Otherwise, SliceAddrRs is set equal to SliceAddrRs of the preceding slice segment containing the coding tree block for which the coding tree block address is CtbAddrTsToRs[ CtbAddrRsToTs[ slice_segment_address ] − 1 ].

**slice_segment_address** specifies the address of the first coding tree block in the slice segment, in coding tree block raster scan of a picture. The length of the slice_segment_address syntax element is Ceil( Log2( PicSizeInCtbsY ) ) bits. The value of slice_segment_address shall be in the range of 0 to PicSizeInCtbsY − 1, inclusive and the value of slice_segment_address shall not be equal to the value of slice_segment_address of any other coded slice segment NAL unit of the same coded picture. When slice_segment_address is not present, it is inferred to be equal to 0.

The variable CtbAddrInRs, specifying a coding tree block address in coding tree block raster scan of a picture, is set equal to slice_segment_address. The variable CtbAddrInTs, specifying a coding tree block address in tile scan, is set equal to CtbAddrRsToTs[ CtbAddrInRs ]. The variable CuQpDeltaVal, specifying the difference between a luma quantization parameter for the coding unit containing cu_qp_delta_abs and its prediction, is set equal to 0.

**slice_reserved_flag**[ i ] has semantics and values that are reserved for future use by ITU-T | ISO/IEC. Decoders shall ignore the presence and value of slice_reserved_flag[ i ].

**slice_type** specifies the coding type of the slice according to Table 7-7.

**Table 7-7 – Name association to slice_type**

| slice_type | Name of slice_type |
|---|---|
| 0 | B (B slice) |
| 1 | P (P slice) |
| 2 | I (I slice) |

When nal_unit_type has a value in the range of BLA_W_LP to RSV_IRAP_VCL23, inclusive, i.e. the picture is an IRAP picture, slice_type shall be equal to 2.

When sps_max_dec_pic_buffering_minus1[ TemporalId ] is equal to 0, slice_type shall be equal to 2.

**pic_output_flag** affects the decoded picture output and removal processes as specified in Annex C. When pic_output_flag is not present, it is inferred to be equal to 1.

**colour_plane_id** specifies the colour plane associated with the current slice RBSP when separate_colour_plane_flag is equal to 1. The value of colour_plane_id shall be in the range of 0 to 2, inclusive. colour_plane_id values 0, 1, and 2 correspond to the Y, Cb, and Cr planes, respectively.

NOTE 1 – There is no dependency between the decoding processes of pictures having different values of colour_plane_id.

**slice_pic_order_cnt_lsb** specifies the picture order count modulo MaxPicOrderCntLsb for the current picture. The length of the slice_pic_order_cnt_lsb syntax element is log2_max_pic_order_cnt_lsb_minus4 + 4 bits. The value of the slice_pic_order_cnt_lsb shall be in the range of 0 to MaxPicOrderCntLsb − 1, inclusive. When slice_pic_order_cnt_lsb is not present, slice_pic_order_cnt_lsb is inferred to be equal to 0, except as specified in subclause 8.3.3.1.

**short_term_ref_pic_set_sps_flag** equal to 1 specifies that the short-term RPS of the current picture is derived based on one of the short_term_ref_pic_set( ) syntax structures in the active SPS that is identified by the syntax element short_term_ref_pic_set_idx in the slice header. short_term_ref_pic_set_sps_flag equal to 0 specifies that the short-term RPS of the current picture is derived based on the short_term_ref_pic_set( ) syntax structure that is directly included in the slice headers of the current picture. When num_short_term_ref_pic_sets is equal to 0, the value of short_term_ref_pic_set_sps_flag shall be equal to 0.

**short_term_ref_pic_set_idx** specifies the index, into the list of the short_term_ref_pic_set( ) syntax structures included in the active SPS, of the short_term_ref_pic_set( ) syntax structure that is used for derivation of the short-term RPS of the current picture. The syntax element short_term_ref_pic_set_idx is represented by Ceil( Log2( num_short_term_ref_pic_sets ) ) bits. When not present, the value of short_term_ref_pic_set_idx is inferred to be equal to 0. The value of short_term_ref_pic_set_idx shall be in the range of 0 to num_short_term_ref_pic_sets − 1, inclusive.

The variable CurrRpsIdx is derived as follows:

– If short_term_ref_pic_set_sps_flag is equal to 1, CurrRpsIdx is set equal to short_term_ref_pic_set_idx.

– Otherwise, CurrRpsIdx is set equal to num_short_term_ref_pic_sets.

**num_long_term_sps** specifies the number of entries in the long-term RPS of the current picture that are derived based the candidate long-term reference pictures specified in the active SPS. The value of num_long_term_sps shall be in the range of 0 to num_long_term_ref_pics_sps, inclusive. When not present, the value of num_long_term_sps is inferred to be equal to 0.

**num_long_term_pics** specifies the number of entries in the long-term RPS of the current picture that are directly signalled in the slice header. When not present, the value of num_long_term_pics is inferred to be equal to 0.

The sum of NumNegativePics[ CurrRpsIdx ], NumPositivePics[ CurrRpsIdx ], num_long_term_sps, and num_long_term_pics shall be less than or equal to sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ].

**lt_idx_sps**[ i ] specifies an index, into the list of candidate long-term reference pictures specified in the active SPS, of the i-th entry in the long-term RPS of the current picture. The number of bits used to represent lt_idx_sps[ i ] is equal to Ceil( Log2( num_long_term_ref_pics_sps ) ). When not present, the value of lt_idx_sps[ i ] is inferred to be equal to 0. The value of lt_idx_sps[ i ] shall be in the range of 0 to num_long_term_ref_pics_sps − 1, inclusive.

**poc_lsb_lt**[ i ] specifies the value of the picture order count modulo MaxPicOrderCntLsb of the i-th entry in the long-term RPS of the current picture. The length of the poc_lsb_lt[ i ] syntax element is log2_max_pic_order_cnt_lsb_minus4 + 4 bits.

**used_by_curr_pic_lt_flag**[ i ] equal to 0 specifies that the i-th entry in the long-term RPS of the current picture is not used for reference by the current picture.

The variables PocLsbLt[ i ] and UsedByCurrPicLt[ i ] are derived as follows:

– If i is less than num_long_term_sps, PocLsbLt[ i ] is set equal to lt_ref_pic_poc_lsb_sps[ lt_idx_sps[ i ] ] and UsedByCurrPicLt[ i ] is set equal to used_by_curr_pic_lt_sps_flag[ lt_idx_sps[ i ] ].

– Otherwise, PocLsbLt[ i ] is set equal to poc_lsb_lt[ i ] and UsedByCurrPicLt[ i ] is set equal to used_by_curr_pic_lt_flag[ i ].

**delta_poc_msb_present_flag**[ i ] equal to 1 specifies that delta_poc_msb_cycle_lt[ i ] is present. delta_poc_msb_present_flag[ i ] equal to 0 specifies that delta_poc_msb_cycle_lt[ i ] is not present.

Let prevTid0Pic be the previous picture in decoding order that has TemporalId equal to 0 and is not a RASL picture, a RADL picture, or a sub-layer non-reference picture. Let setOfPrevPocVals be a set consisting of the following:

– the PicOrderCntVal of prevTid0Pic,

– the PicOrderCntVal of each picture in the RPS of prevTid0Pic,

– the PicOrderCntVal of each picture that follows prevTid0Pic in decoding order and precedes the current picture in decoding order.

When there is more than one value in setOfPrevPocVals for which the value modulo MaxPicOrderCntLsb is equal to PocLsbLt[ i ], delta_poc_msb_present_flag[ i ] shall be equal to 1.

**delta_poc_msb_cycle_lt**[ i ] is used to determine the value of the most significant bits of the picture order count value of the i-th entry in the long-term RPS of the current picture. When delta_poc_msb_cycle_lt[ i ] is not present, it is inferred to be equal to 0.

The variable DeltaPocMsbCycleLt[ i ] is derived as follows:

```
if( i = = 0 || i = = num_long_term_sps )
    DeltaPocMsbCycleLt[ i ] = delta_poc_msb_cycle_lt[ i ]
else                                                                                          (7-38)
    DeltaPocMsbCycleLt[ i ] = delta_poc_msb_cycle_lt[ i ] + DeltaPocMsbCycleLt[ i − 1 ]
```

**slice_temporal_mvp_enabled_flag** specifies whether temporal motion vector predictors can be used for inter prediction. If slice_temporal_mvp_enabled_flag is equal to 0, the syntax elements of the current picture shall be constrained such that no temporal motion vector predictor is used in decoding of the current picture. Otherwise (slice_temporal_mvp_enabled_flag is equal to 1), temporal motion vector predictors may be used in decoding of the current picture. When not present, the value of slice_temporal_mvp_enabled_flag is inferred to be equal to 0.

When both slice_temporal_mvp_enabled_flag and TemporalId are equal to 0, the syntax elements for all coded pictures that follow the current picture in decoding order shall be constrained such that no temporal motion vector from any picture that precedes the current picture in decoding order is used in decoding of any coded picture that follows the current picture in decoding order.

NOTE 2 – When slice_temporal_mvp_enabled_flag is equal to 0 in an I slice, it has no impact on the normative decoding process of the picture but merely expresses a bitstream constraint.

NOTE 3 – When slice_temporal_mvp_enabled_flag is equal to 0 in a slice with TemporalId are equal to 0, decoders may empty "motion vector storage" for all reference pictures in the decoded picture buffer.

**slice_sao_luma_flag** equal to 1 specifies that SAO is enabled for the luma component in the current slice; slice_sao_luma_flag equal to 0 specifies that SAO is disabled for the luma component in the current slice. When slice_sao_luma_flag is not present, it is inferred to be equal to 0.

**slice_sao_chroma_flag** equal to 1 specifies that SAO is enabled for the chroma component in the current slice; slice_sao_chroma_flag equal to 0 specifies that SAO is disabled for the chroma component in the current slice. When slice_sao_chroma_flag is not present, it is inferred to be equal to 0.

**num_ref_idx_active_override_flag** equal to 1 specifies that the syntax element num_ref_idx_l0_active_minus1 is present for P and B slices and that the syntax element num_ref_idx_l1_active_minus1 is present for B slices. num_ref_idx_active_override_flag equal to 0 specifies that the syntax elements num_ref_idx_l0_active_minus1 and num_ref_idx_l1_active_minus1 are not present.

**num_ref_idx_l0_active_minus1** specifies the maximum reference index for reference picture list 0 that may be used to decode the slice. num_ref_idx_l0_active_minus1 shall be in the range of 0 to 14, inclusive. When the current slice is a P or B slice and num_ref_idx_l0_active_minus1 is not present, num_ref_idx_l0_active_minus1 is inferred to be equal to num_ref_idx_l0_default_active_minus1.

**num_ref_idx_l1_active_minus1** specifies the maximum reference index for reference picture list 1 that may be used to decode the slice. num_ref_idx_l1_active_minus1 shall be in the range of 0 to 14, inclusive. When num_ref_idx_l1_active_minus1 is not present, num_ref_idx_l1_active_minus1 is inferred to be equal to num_ref_idx_l1_default_active_minus1.

**mvd_l1_zero_flag** equal to 1 indicates that the mvd_coding( x0, y0, 1 ) syntax structure is not parsed and MvdL1[ x0 ][ y0 ][ compIdx ] is set equal to 0 for compIdx = 0..1. mvd_l1_zero_flag equal to 0 indicates that the mvd_coding( x0, y0, 1 ) syntax structure is parsed.

**cabac_init_flag** specifies the method for determining the initialization table used in the initialization process for context variables. When cabac_init_flag is not present, it is inferred to be equal to 0.

**collocated_from_l0_flag** equal to 1 specifies that the collocated picture used for temporal motion vector prediction is derived from reference picture list 0. collocated_from_l0_flag equal to 0 specifies that the collocated picture used for temporal motion vector prediction is derived from reference picture list 1. When collocated_from_l0_flag is not present, it is inferred to be equal to 1.

**collocated_ref_idx** specifies the reference index of the collocated picture used for temporal motion vector prediction.

When slice_type is equal to P or when slice_type is equal to B and collocated_from_l0 is equal to 1, collocated_ref_idx refers to a picture in list 0, and the value of collocated_ref_idx shall be in the range of 0 to num_ref_idx_l0_active_minus1, inclusive.

When slice_type is equal to B and collocated_from_l0 is equal to 0, collocated_ref_idx refers to a picture in list 1, and the value of collocated_ref_idx shall be in the range of 0 to num_ref_idx_l1_active_minus1, inclusive.

It is a requirement of bitstream conformance that the picture referred to by collocated_ref_idx shall be the same for all slices of a coded picture.

**five_minus_max_num_merge_cand** specifies the maximum number of merging MVP candidates supported in the slice subtracted from 5. The maximum number of merging MVP candidates, MaxNumMergeCand is derived as follows:

$$\text{MaxNumMergeCand} = 5 - \text{five\_minus\_max\_num\_merge\_cand} \quad (7\text{-}39)$$

The value of MaxNumMergeCand shall be in the range of 1 to 5, inclusive.

**slice_qp_delta** specifies the initial value of $\text{Qp}_\text{Y}$ to be used for the coding blocks in the slice until modified by the value of CuQpDeltaVal in the coding unit layer. The initial value of the $\text{Qp}_\text{Y}$ quantization parameter for the slice, $\text{SliceQp}_\text{Y}$, is derived as follows:

$$\text{SliceQp}_\text{Y} = 26 + \text{init\_qp\_minus26} + \text{slice\_qp\_delta} \quad (7\text{-}40)$$

The value of $\text{SliceQp}_\text{Y}$ shall be in the range of $-\text{QpBdOffset}_\text{Y}$ to +51, inclusive.

**slice_cb_qp_offset** specifies a difference to be added to the value of pps_cb_qp_offset when determining the value of the $\text{Qp}'_{\text{Cb}}$ quantization parameter. The value of slice_cb_qp_offset shall be in the range of −12 to +12, inclusive. When slice_cb_qp_offset is not present, it is inferred to be equal to 0. The value of pps_cb_qp_offset + slice_cb_qp_offset shall be in the range of −12 to +12, inclusive.

**slice_cr_qp_offset** specifies a difference to be added to the value of pps_cr_qp_offset when determining the value of the $\text{Qp}'_{\text{Cr}}$ quantization parameter. The value of slice_cr_qp_offset shall be in the range of −12 to +12, inclusive. When slice_cr_qp_offset is not present, it is inferred to be equal to 0. The value of pps_cr_qp_offset + slice_cr_qp_offset shall be in the range of −12 to +12, inclusive.

**deblocking_filter_override_flag** equal to 1 specifies that deblocking parameters are present in the slice header. deblocking_filter_override_flag equal to 0 specifies that deblocking parameters are not present in the slice header. When not present, the value of deblocking_filter_override_flag is inferred to be equal to 0.

**slice_deblocking_filter_disabled_flag** equal to 1 specifies that the operation of the deblocking filter is not applied for the current slice. slice_deblocking_filter_disabled_flag equal to 0 specifies that the operation of the deblocking filter is applied for the current slice. When slice_deblocking_filter_disabled_flag is not present, it is inferred to be equal to pps_deblocking_filter_disabled_flag.

**slice_beta_offset_div2** and **slice_tc_offset_div2** specify the deblocking parameter offsets for β and tC (divided by 2) for the current slice. The values of slice_beta_offset_div2 and slice_tc_offset_div2 shall both be in the range of −6 to 6, inclusive. When not present, the values of slice_beta_offset_div2 and slice_tc_offset_div2 are inferred to be equal to pps_beta_offset_div2 and pps_tc_offset_div2, respectively.

**slice_loop_filter_across_slices_enabled_flag** equal to 1 specifies that in-loop filtering operations may be performed across the left and upper boundaries of the current slice. slice_loop_filter_across_slices_enabled_flag equal to 0 specifies that in-loop operations are not performed across left and upper boundaries of the current slice. The in-loop filtering operations include the deblocking filter and sample adaptive offset filter. When slice_loop_filter_across_slices_enabled_flag is not present, it is inferred to be equal to pps_loop_filter_across_slices_enabled_flag.

**num_entry_point_offsets** specifies the number of entry_point_offset_minus1[ i ] syntax elements in the slice header. When not present, the value of num_entry_point_offsets is inferred to be equal to 0.

The value of num_entry_point_offsets is constrained as follows:

– If tiles_enabled_flag is equal to 0 and entropy_coding_sync_enabled_flag is equal to 1, the value of num_entry_point_offsets shall be in the range of 0 to PicHeightInCtbsY − 1, inclusive.

– Otherwise, if tiles_enabled_flag is equal to 1 and entropy_coding_sync_enabled_flag is equal to 0, the value of num_entry_point_offsets shall be in the range of 0 to ( num_tile_columns_minus1 + 1 ) * ( num_tile_rows_minus1 + 1 ) − 1, inclusive.

– Otherwise, when tiles_enabled_flag is equal to 1 and entropy_coding_sync_enabled_flag is equal to 1, the value of num_entry_point_offsets shall be in the range of 0 to ( num_tile_columns_minus1 + 1 ) * PicHeightInCtbsY − 1, inclusive.

**offset_len_minus1** plus 1 specifies the length, in bits, of the entry_point_offset_minus1[ i ] syntax elements. The value of offset_len_minus1 shall be in the range of 0 to 31, inclusive.

**entry_point_offset_minus1**[ i ] plus 1 specifies the i-th entry point offset in bytes, and is represented by offset_len_minus1 plus 1 bits. The slice segment data that follows the slice segment header consists of num_entry_point_offsets + 1 subsets, with subset index values ranging from 0 to num_entry_point_offsets, inclusive. The first byte of the slice segment data is considered byte 0. When present, emulation prevention bytes that appear in the slice segment data portion of the coded slice segment NAL unit are counted as part of the slice segment data for purposes of subset identification. Subset 0 consists of bytes 0 to entry_point_offset_minus1[ 0 ], inclusive, of the coded slice segment data, subset k, with k in the range of 1 to num_entry_point_offsets − 1, inclusive, consists of bytes firstByte[ k ] to lastByte[ k ], inclusive, of the coded slice segment data with firstByte[ k ] and lastByte[ k ] defined as:

$$\text{firstByte}[\,k\,] = \sum_{n=1}^{k}(\text{entry\_point\_offset\_minus1}[n-1]+1) \qquad (7\text{-}41)$$

$$\text{lastByte}[\,k\,] = \text{firstByte}[\,k\,] + \text{entry\_point\_offset\_minus1}[\,k\,] \qquad (7\text{-}42)$$

The last subset (with subset index equal to num_entry_point_offsets) consists of the remaining bytes of the coded slice segment data.

When tiles_enabled_flag is equal to 1 and entropy_coding_sync_enabled_flag is equal to 0, each subset shall consist of all coded bits of all coding tree units in the slice segment that are within the same tile, and the number of subsets (i.e. the value of num_entry_point_offsets + 1) shall be equal to the number of tiles that contain coding tree units that are in the coded slice segment.

NOTE 4 – When tiles_enabled_flag is equal to 1 and entropy_coding_sync_enabled_flag is equal to 0, each slice must include either a subset of the coding tree units of one tile (in which case the syntax element entry_point_offset_minus1[ i ] is not present) or must include all coding tree units of an integer number of complete tiles.

When tiles_enabled_flag is equal to 0 and entropy_coding_sync_enabled_flag is equal to 1, each subset k with k in the range of 0 to num_entry_point_offsets, inclusive, shall consist of all coded bits of all coding tree units in the slice segment that include luma coding tree blocks that are in the same luma coding tree block row of the picture, and the number of subsets (i.e. the value of num_entry_point_offsets + 1) shall be equal to the number of coding tree block rows of the picture that contain coding tree units that are in the coded slice segment.

NOTE 5 – The last subset (i.e. subset k for k equal to num_entry_point_offsets) may or may not contain all coding tree units that include luma coding tree blocks that are in a luma coding tree block row of the picture.

When tiles_enabled_flag is equal to 1 and entropy_coding_sync_enabled_flag is equal to 1, each subset k with k in the range of 0 to num_entry_point_offsets, inclusive, shall consist of all coded bits of all coding tree units in the slice segment that include luma coding tree blocks that are in the same luma coding tree block row of a tile, and the number of subsets (i.e. the value of num_entry_point_offsets + 1) shall be equal to the number of luma coding tree block rows of a tile that contain coding tree units that are in the coded slice segment.

**slice_segment_header_extension_length** specifies the length of the slice segment header extension data in bytes, not including the bits used for signalling slice_segment_header_extension_length itself. The value of slice_segment_header_extension_length shall be in the range of 0 to 256, inclusive.

**slice_segment_header_extension_data_byte** may have any value. Decoders shall ignore the value of slice_segment_header_extension_data_byte. Its value does not affect decoder conformance to profiles specified in this version of this Specification.

### 7.4.7.2 Reference picture list modification semantics

**ref_pic_list_modification_flag_l0** equal to 1 indicates that reference picture list 0 is specified explicitly by a list of list_entry_l0[ i ] values. ref_pic_list_modification_flag_l0 equal to 0 indicates that reference picture list 0 is determined implicitly. When ref_pic_list_modification_flag_l0 is not present in the slice header, it is inferred to be equal to 0.

**list_entry_l0**[ i ] specifies the index of the reference picture in RefPicListTemp0 to be placed at the current position of reference picture list 0. The length of the list_entry_l0[ i ] syntax element is Ceil( Log2( NumPocTotalCurr ) ) bits. The value of list_entry_l0[ i ] shall be in the range of 0 to NumPocTotalCurr − 1, inclusive. When the syntax element list_entry_l0[ i ] is not present in the slice header, it is inferred to be equal to 0.

The variable NumPocTotalCurr is derived as follows:

```
NumPocTotalCurr = 0
for( i = 0; i < NumNegativePics[ CurrRpsIdx ]; i++ )
    if( UsedByCurrPicS0[ CurrRpsIdx ][ i ] )
        NumPocTotalCurr++
for( i = 0; i < NumPositivePics[ CurrRpsIdx ]; i++)                    (7-43)
    if( UsedByCurrPicS1[ CurrRpsIdx ][ i ] )
        NumPocTotalCurr++
for( i = 0; i < num_long_term_sps + num_long_term_pics; i++ )
    if( UsedByCurrPicLt[ i ] )
        NumPocTotalCurr++
```

**ref_pic_list_modification_flag_l1** equal to 1 indicates that reference picture list 1 is specified explicitly by a list of list_entry_l1[ i ] values. ref_pic_list_modification_flag_l1 equal to 0 indicates that reference picture list 1 is determined implicitly. When ref_pic_list_modification_flag_l1 is not present in the slice header, it is inferred to be equal to 0.

**list_entry_l1**[ i ] specifies the index of the reference picture in RefPicListTemp1 to be placed at the current position of reference picture list 1. The length of the list_entry_l1[ i ] syntax element is Ceil( Log2( NumPocTotalCurr ) ) bits. The value of list_entry_l1[ i ] shall be in the range of 0 to NumPocTotalCurr − 1, inclusive. When the syntax element list_entry_l1[ i ] is not present in the slice header, it is inferred to be equal to 0.

### 7.4.7.3 Weighted prediction parameters semantics

**luma_log2_weight_denom** is the base 2 logarithm of the denominator for all luma weighting factors. The value of luma_log2_weight_denom shall be in the range of 0 to 7, inclusive.

**delta_chroma_log2_weight_denom** is the difference of the base 2 logarithm of the denominator for all chroma weighting factors.

The variable ChromaLog2WeightDenom is derived to be equal to luma_log2_weight_denom + delta_chroma_log2_weight_denom, and the value shall be in the range of 0 to 7, inclusive.

**luma_weight_l0_flag**[ i ] equal to 1 specifies that weighting factors for the luma component of list 0 prediction using RefPicList0[ i ] are present. luma_weight_l0_flag[ i ] equal to 0 specifies that these weighting factors are not present.

**chroma_weight_l0_flag[ i ]** equal to 1 specifies that weighting factors for the chroma prediction values of list 0 prediction using RefPicList0[ i ] are present. chroma_weight_l0_flag[ i ] equal to 0 specifies that these weighting factors are not present. When chroma_weight_l0_flag[ i ] is not present, it is inferred to be equal to 0.

**delta_luma_weight_l0[ i ]** is the difference of the weighting factor applied to the luma prediction value for list 0 prediction using RefPicList0[ i ].

The variable LumaWeightL0[ i ] is derived to be equal to ( 1 << luma_log2_weight_denom ) + delta_luma_weight_l0[ i ]. When luma_weight_l0_flag[ i ] is equal to 1, the value of delta_luma_weight_l0[ i ] shall be in the range of −128 to 127, inclusive. When luma_weight_l0_flag[ i ] is equal to 0, LumaWeightL0[ i ] is inferred to be equal to $2^{\text{luma\_log2\_weight\_denom}}$.

**luma_offset_l0[ i ]** is the additive offset applied to the luma prediction value for list 0 prediction using RefPicList0[ i ]. The value of luma_offset_l0[ i ] shall be in the range of −128 to 127, inclusive. When luma_weight_l0_flag[ i ] is equal to 0, luma_offset_l0[ i ] is inferred as equal to 0.

**delta_chroma_weight_l0[ i ][ j ]** is the difference of the weighting factor applied to the chroma prediction values for list 0 prediction using RefPicList0[ i ] with j equal to 0 for Cb and j equal to 1 for Cr.

The variable ChromaWeightL0[ i ][ j ] is derived to be equal to ( 1 << ChromaLog2WeightDenom ) + delta_chroma_weight_l0[ i ][ j ]. When chroma_weight_l0_flag[ i ] is equal to 1, the value of delta_chroma_weight_l0[ i ][ j ] shall be in the range of −128 to 127, inclusive. When chroma_weight_l0_flag[ i ] is equal to 0**,** ChromaWeightL0[ i ][ j ] is inferred to be equal to $2^{\text{ChromaLog2WeightDenom}}$.

**delta_chroma_offset_l0[ i ][ j ]** is the difference of the additive offset applied to the chroma prediction values for list 0 prediction using RefPicList0[ i ] with j equal to 0 for Cb and j equal to 1 for Cr.

The variable ChromaOffsetL0[ i ][ j ] is derived as follows:

```
ChromaOffsetL0[ i ][ j ] = Clip3( −128, 127, ( delta_chroma_offset_l0[ i ][ j ] −                (7-44)
        ( ( 128 * ChromaWeightL0[ i ][ j ] ) >>  ChromaLog2WeightDenom ) + 128 ) )
```

The value of delta_chroma_offset_l0[ i ][ j ] shall be in the range of −512 to 511, inclusive. When chroma_weight_l0_flag[ i ] is equal to 0**,** ChromaOffsetL0[ i ][ j ] is inferred to be equal to 0.

**luma_weight_l1_flag**[ i ], **chroma_weight_l1_flag**[ i ], **delta_luma_weight_l1**[ i ], **luma_offset_l1**[ i ], **delta_chroma_weight_l1**[ i ][ j ], and **delta_chroma_offset_l1**[ i ][ j ] have the same semantics as luma_weight_l0_flag[ i ], chroma_weight_l0_flag[ i ], delta_luma_weight_l0[ i ], luma_offset_l0[ i ], delta_chroma_weight_l0[ i ][ j ], and delta_chroma_offset_l0[ i ][ j ], respectively, with l0, L0, list 0, and List0 replaced by l1, L1, list 1, and List1, respectively.

The variable sumWeightL0Flags is derived to be equal to the sum of luma_weight_l0_flag[ i ] + 2 * chroma_weight_l0_flag[ i ], for i = 0..num_ref_idx_l0_active_minus1.

When slice_type is equal to B, the variable sumWeightL1Flags is derived to be equal to the sum of luma_weight_l1_flag[ i ] + 2 * chroma_weight_l1_flag[ i ], for i = 0..num_ref_idx_l1_active_minus1.

It is a requirement of bitstream conformance that, when slice_type is equal to P, sumWeightL0Flags shall be less than or equal to 24, and when slice_type is equal to B, the sum of sumWeightL0Flags and sumWeightL1Flags shall be less than or equal to 24.

### 7.4.8 Short-term reference picture set semantics

A short_term_ref_pic_set( stRpsIdx ) syntax structure may be present in an SPS or in a slice header. Depending on whether the syntax structure is included in a slice header or an SPS, the following applies:

– If present in a slice header, the short_term_ref_pic_set( stRpsIdx ) syntax structure specifies the short-term RPS of the current picture (the picture containing the slice), and the following applies:
  – The content of the short_term_ref_pic_set( stRpsIdx ) syntax structure shall be the same in all slice headers of the current picture.
  – The value of stRpsIdx shall be equal to the syntax element num_short_term_ref_pic_sets in the active SPS.
  – The short-term RPS of the current picture is also referred to as the num_short_term_ref_pic_sets-th candidate short-term RPS in the semantics specified in the remainder of this subclause.
– Otherwise (present in an SPS), the short_term_ref_pic_set( stRpsIdx ) syntax structure specifies a candidate short-term RPS, and the term "the current picture" in the semantics specified in the remainder of this subclause refers to each picture that has short_term_ref_pic_set_idx equal to stRpsIdx in a CVS that has the SPS as the active SPS.

**inter_ref_pic_set_prediction_flag** equal to 1 specifies that the stRpsIdx-th candidate short-term RPS is predicted from another candidate short-term RPS, which is referred to as the source candidate short-term RPS. When inter_ref_pic_set_prediction_flag is not present, it is inferred to be equal to 0.

**delta_idx_minus1** plus 1 specifies the difference between the value of stRpsIdx and the index, into the list of the candidate short-term RPSs specified in the SPS, of the source candidate short-term RPS. The value of delta_idx_minus1 shall be in the range of 0 to stRpsIdx − 1, inclusive. When delta_idx_minus1 is not present, it is inferred to be equal to 0.

The variable RefRpsIdx is derived as follows:

RefRpsIdx = stRpsIdx − ( delta_idx_minus1 + 1 ) (7-45)

**delta_rps_sign** and **abs_delta_rps_minus1** together specify the value of the variable deltaRps as follows:

deltaRps = ( 1 − 2 * delta_rps_sign ) * ( abs_delta_rps_minus1 + 1 ) (7-46)

The variable deltaRps represents the value to be added to the picture order count difference values of the source candidate short-term RPS to obtain the picture order count difference values of the stRpsIdx-th candidate short-term RPS. The value of abs_delta_rps_minus1 shall be in the range of 0 to $2^{15} − 1$, inclusive.

**used_by_curr_pic_flag**[ j ] equal to 0 specifies that the j-th entry in the source candidate short-term RPS is not used for reference by the current picture.

**use_delta_flag**[ j ] equal to 1 specifies that the j-th entry in the source candidate short-term RPS is included in the stRpsIdx-th candidate short-term RPS. use_delta_flag[ j ] equal to 0 specifies that the j-th entry in the source candidate short-term RPS is not included in the stRpsIdx-th candidate short-term RPS. When use_delta_flag[ j ] is not present, its value is inferred to be equal to 1.

When inter_ref_pic_set_prediction_flag is equal to 1, the variables DeltaPocS0[ stRpsIdx ][ i ], UsedByCurrPicS0[ stRpsIdx ][ i ], NumNegativePics[ stRpsIdx ], DeltaPocS1[ stRpsIdx ][ i ], UsedByCurrPicS1[ stRpsIdx ][ i ], and NumPositivePics[ stRpsIdx ] are derived as follows:

```
i = 0
for( j = NumPositivePics[ RefRpsIdx ] − 1; j  >=  0; j− − ) {
    dPoc = DeltaPocS1[ RefRpsIdx ][ j ] + deltaRps
    if( dPoc < 0  &&  use_delta_flag[ NumNegativePics[ RefRpsIdx ] + j ] ) {
        DeltaPocS0[ stRpsIdx ][ i ] = dPoc
        UsedByCurrPicS0[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ NumNegativePics[ RefRpsIdx ] + j ]
    }
}
if( deltaRps < 0  &&  use_delta_flag[ NumDeltaPocs[ RefRpsIdx ] ] ) {                (7-47)
    DeltaPocS0[ stRpsIdx ][ i ] = deltaRps
    UsedByCurrPicS0[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ NumDeltaPocs[ RefRpsIdx ] ]
}
for( j = 0; j < NumNegativePics[ RefRpsIdx ]; j++ ) {
    dPoc = DeltaPocS0[ RefRpsIdx ][ j ] + deltaRps
    if( dPoc < 0  &&  use_delta_flag[ j ] ) {
        DeltaPocS0[ stRpsIdx ][ i ] = dPoc
        UsedByCurrPicS0[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ j ]
    }
}
NumNegativePics[ stRpsIdx ] = i

i = 0
for( j = NumNegativePics[ RefRpsIdx ] − 1; j  >=  0; j− − ) {
    dPoc = DeltaPocS0[ RefRpsIdx ][ j ] + deltaRps
    if( dPoc > 0  &&  use_delta_flag[ j ] ) {
        DeltaPocS1[ stRpsIdx ][ i ] = dPoc
        UsedByCurrPicS1[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ j ]
    }
}
if( deltaRps > 0  &&  use_delta_flag[ NumDeltaPocs[ RefRpsIdx ] ] ) {                    (7-48)
    DeltaPocS1[ stRpsIdx ][ i ] = deltaRps
    UsedByCurrPicS1[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ NumDeltaPocs[ RefRpsIdx ] ]
}
for( j = 0; j < NumPositivePics[ RefRpsIdx ]; j++) {
    dPoc = DeltaPocS1[ RefRpsIdx ][ j ] + deltaRps
    if( dPoc > 0  &&  use_delta_flag[ NumNegativePics[ RefRpsIdx ] + j ] ) {
        DeltaPocS1[ stRpsIdx ][ i ] = dPoc
        UsedByCurrPicS1[ stRpsIdx ][ i++ ] = used_by_curr_pic_flag[ NumNegativePics[ RefRpsIdx ] + j ]
    }
}
NumPositivePics[ stRpsIdx ] = i
```

**num_negative_pics** specifies the number of entries in the stRpsIdx-th candidate short-term RPS that have picture order count values less than the picture order count value of the current picture. The value of num_negative_pics shall be in the range of 0 to sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ], inclusive.

**num_positive_pics** specifies the number of entries in the stRpsIdx-th candidate short-term RPS that have picture order count values greater than the picture order count value of the current picture. The value of num_positive_pics shall be in the range of 0 to sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ] − num_negative_pics, inclusive.

**delta_poc_s0_minus1**[ i ] plus 1, when i is equal to 0, specifies the difference between the picture order count values of the current picture and i-th entry in the stRpsIdx-th candidate short-term RPS that has picture order count value less than that of the current picture, or, when i is greater than 0, specifies the difference between the picture order count values of the i-th entry and the ( i + 1 )-th entry in the stRpsIdx-th candidate short-term RPS that have picture order count values less than the picture order count value of the current picture. The value of delta_poc_s0_minus1[ i ] shall be in the range of 0 to $2^{15} - 1$, inclusive.

**used_by_curr_pic_s0_flag**[ i ] equal to 0 specifies that the i-th entry in the stRpsIdx-th candidate short-term RPS that has picture order count value less than that of the current picture is not used for reference by the current picture.

**delta_poc_s1_minus1**[ i ] plus 1, when i is equal to 0, specifies the difference between the picture order count values of the current picture and the i-th entry in the stRpsIdx-th candidate short-term RPS that has picture order count value greater than that of the current picture, or, when i is greater than 0, specifies the difference between the picture order count values of the ( i + 1 )-th entry and i-th entry in the current candidate short-term RPS that have picture order count values greater than the picture order count value of the current picture. The value of delta_poc_s1_minus1[ i ] shall be in the range of 0 to $2^{15} - 1$, inclusive.

**used_by_curr_pic_s1_flag**[ i ] equal to 0 specifies that the i-th entry in the current candidate short-term RPS that has picture order count value greater than that of the current picture is not used for reference by the current picture.

When inter_ref_pic_set_prediction_flag is equal to 0, the variables NumNegativePics[ stRpsIdx ], NumPositivePics[ stRpsIdx ], UsedByCurrPicS0[ stRpsIdx ][ i ], UsedByCurrPicS1[ stRpsIdx ][ i ], DeltaPocS0[ stRpsIdx ][ i ], and DeltaPocS1[ stRpsIdx ][ i ] are derived as follows:

NumNegativePics[ stRpsIdx ] = num_negative_pics (7-49)

NumPositivePics[ stRpsIdx ] = num_positive_pics (7-50)

UsedByCurrPicS0[ stRpsIdx ][ i ] = used_by_curr_pic_s0_flag[ i ] (7-51)

UsedByCurrPicS1[ stRpsIdx ][ i ] = used_by_curr_pic_s1_flag[ i ] (7-52)

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

DeltaPocS0[ stRpsIdx ][ i ] = −( delta_poc_s0_minus1[ i ] + 1 ) (7-53)

DeltaPocS1[ stRpsIdx ][ i ] = delta_poc_s1_minus1[ i ] + 1 (7-54)

– Otherwise, the following applies:

DeltaPocS0[ stRpsIdx ][ i ] = DeltaPocS0[ stRpsIdx ][ i − 1 ] − ( delta_poc_s0_minus1[ i ] + 1 ) (7-55)

DeltaPocS1[ stRpsIdx ][ i ] = DeltaPocS1[ stRpsIdx ][ i − 1 ] + ( delta_poc_s1_minus1[ i ] + 1 ) (7-56)

The variable NumDeltaPocs[ stRpsIdx ] is derived as follows:

NumDeltaPocs[ stRpsIdx ] = NumNegativePics[ stRpsIdx ] + NumPositivePics[ stRpsIdx ] (7-57)

### 7.4.9 Slice segment data semantics

#### 7.4.9.1 General slice segment data semantics

**end_of_slice_segment_flag** equal to 0 specifies that another coding tree unit is following in the slice. end_of_slice_segment_flag equal to 1 specifies the end of the slice segment, i.e. that no further coding tree unit follows in the slice segment.

**end_of_sub_stream_one_bit** shall be equal to 1.

#### 7.4.9.2 Coding tree unit semantics

The coding tree unit is the root node of the coding quadtree structure.

#### 7.4.9.3 Sample adaptive offset semantics

**sao_merge_left_flag** equal to 1 specifies that the syntax elements sao_type_idx_luma, sao_type_idx_chroma, sao_band_position, sao_eo_class_luma, sao_eo_class_chroma, sao_offset_abs, and sao_offset_sign are derived from the corresponding syntax elements of the left coding tree block. sao_merge_left_flag equal to 0 specifies that these syntax elements are not derived from the corresponding syntax elements of the left coding tree block. When sao_merge_left_flag is not present, it is inferred to be equal to 0.

**sao_merge_up_flag** equal to 1 specifies that the syntax elements sao_type_idx_luma, sao_type_idx_chroma, sao_band_position, sao_eo_class_luma, sao_eo_class_chroma, sao_offset_abs, and sao_offset_sign are derived from the corresponding syntax elements of the above coding tree block. sao_merge_up_flag equal to 0 specifies that these syntax elements are not derived from the corresponding syntax elements of the above coding tree block. When sao_merge_up_flag is not present, it is inferred to be equal to 0.

**sao_type_idx_luma** specifies the offset type for the luma component. The array SaoTypeIdx[ cIdx ][ rx ][ ry ] specifies the offset type as specified in Table 7-8 for the coding tree block at the location ( rx, ry ) for the colour component cIdx. The value of SaoTypeIdx[ 0 ][ rx ][ ry ] is derived as follows:

– If sao_type_idx_luma is present, SaoTypeIdx[ 0 ][ rx ][ ry ] is set equal to sao_type_idx_luma.

– Otherwise (sao_type_idx_luma is not present), SaoTypeIdx[ 0 ][ rx ][ ry ] is derived as follows:

  – If sao_merge_left_flag is equal to 1, SaoTypeIdx[ 0 ][ rx ][ ry ] is set equal to SaoTypeIdx[ 0 ][ rx − 1 ][ ry ].

  – Otherwise, if sao_merge_up_flag is equal to 1, SaoTypeIdx[ 0 ][ rx ][ ry ] is set equal to SaoTypeIdx[ 0 ][ rx ][ ry − 1 ].

  – Otherwise, SaoTypeIdx[ 0 ][ rx ][ ry ] is set equal to 0.

**sao_type_idx_chroma** specifies the offset type for the chroma components. The values of SaoTypeIdx[ cIdx ][ rx ][ ry ] are derived as follows for cIdx equal to 1..2:

– If sao_type_idx_chroma is present, SaoTypeIdx[ cIdx ][ rx ][ ry ] is set equal to sao_type_idx_chroma.

– Otherwise (sao_type_idx_chroma is not present), SaoTypeIdx[ cIdx ][ rx ][ ry ] is derived as follows:

  – If sao_merge_left_flag is equal to 1, SaoTypeIdx[ cIdx ][ rx ][ ry ] is set equal to SaoTypeIdx[ cIdx ][ rx − 1 ][ ry ].

  – Otherwise, if sao_merge_up_flag is equal to 1, SaoTypeIdx[ cIdx ][ rx ][ ry ] is set equal to SaoTypeIdx[ cIdx ][ rx ][ ry − 1 ].
  – Otherwise, SaoTypeIdx[ cIdx ][ rx ][ ry ] is set equal to 0.

**Table 7-8 – Specification of the SAO type**

| **SaoTypeIdx[ cIdx ][ rx ][ ry ]** | **SAO type (informative)** |
|---|---|
| 0 | Not applied |
| 1 | Band offset |
| 2 | Edge offset |

**sao_offset_abs**[ cIdx ][ rx ][ ry ][ i ] specifies the offset value of i-th category for the coding tree block at the location ( rx, ry ) for the colour component cIdx.

When sao_offset_abs[ cIdx ][ rx ][ ry ][ i ] is not present, it is inferred as follows:

– If sao_merge_left_flag is equal to 1, sao_offset_abs[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal to sao_offset_abs[ cIdx ][ rx − 1 ][ ry ][ i ].
– Otherwise, if sao_merge_up_flag is equal to 1, sao_offset_abs[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal to sao_offset_abs[ cIdx ][ rx ][ ry − 1 ][ i ].
– Otherwise, sao_offset_abs[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal to 0.

**sao_offset_sign**[ cIdx ][ rx ][ ry ][ i ] specifies the sign of the offset value of i-th category for the coding tree block at the location ( rx, ry ) for the colour component cIdx when SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 1.

When sao_offset_sign[ cIdx ][ rx ][ ry ][ i ] is not present, it is inferred as follows:

– If sao_merge_left_flag is equal to 1, sao_offset_sign[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal to sao_offset_sign[ cIdx ][ rx − 1 ][ ry ][ i ].
– Otherwise, if sao_merge_up_flag is equal to 1, sao_offset_sign[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal to sao_offset_sign[ cIdx ][ rx ][ ry − 1 ][ i ].
– Otherwise, sao_offset_sign[ cIdx ][ rx ][ ry ][ i ] is inferred to be equal 0.

The variable offsetSign is derived as follows:

– If SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 2 and i is equal to 2 or 3, offsetSign is set equal to −1.
– Otherwise, if SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 2 and i is equal to 0 or 1, offsetSign is set equal to 1.
– Otherwise (SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 1), the following applies:
  – If sao_offset_sign[ cIdx ][ rx ][ ry ][ i ] is equal to 0, offsetSign is set equal to equal to 1.
  – Otherwise, offsetSign is set equal to equal to −1.

The variable bitDepth is derived as follows:

– If cIdx is equal to 0, bitDepth is set equal to $\text{BitDepth}_Y$.
– Otherwise (cIdx is equal to 1 or 2), bitDepth is set equal to $\text{BitDepth}_C$.

The list SaoOffsetVal[ cIdx ][ rx ][ ry ][ i ] for i ranging from 0 to 4, inclusive, is derived as follows:

```
SaoOffsetVal[ cIdx ][ rx ][ ry ][ 0 ] = 0
for( i = 0; i < 4; i++ )
SaoOffsetVal[ cIdx ][ rx ][ ry ][ i + 1 ] =                                    (7-58)
          offsetSign * sao_offset_abs[ cIdx ][ rx ][ ry ][ i ]  <<  ( bitDepth − Min( bitDepth, 10 ) )
```

**sao_band_position**[ cIdx ][ rx ][ ry ] specifies the displacement of the band offset of the sample range when SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 1.

When sao_band_position[ cIdx ][ rx ][ ry ] is not present, it is inferred as follows:

– If sao_merge_left_flag is equal to 1, sao_band_position[ cIdx ][ rx ][ ry ] is inferred to be equal to sao_band_position[ cIdx ][ rx − 1 ][ ry ].

– Otherwise, if sao_merge_up_flag is equal to 1, sao_band_position[ cIdx ][ rx ][ ry ] is inferred to be equal to sao_band_position[ cIdx ][ rx ][ ry − 1 ].

– Otherwise, sao_band_position[ cIdx ][ rx ][ ry ] is inferred to be equal to 0.

**sao_eo_class_luma** specifies the edge offset class for the luma component. The array SaoEoClass[ cIdx ][ rx ][ ry ] specifies the offset type as specified in Table 7-9 for the coding tree block at the location ( rx, ry ) for the colour component cIdx. The value of SaoEoClass[ 0 ][ rx ][ ry ] is derived as follows:

– If sao_eo_class_luma is present, SaoEoClass[ 0 ][ rx ][ ry ] is set equal to sao_eo_class_luma.

– Otherwise (sao_eo_class_luma is not present), SaoEoClass[ 0 ][ rx ][ ry ] is derived as follows:

  – If sao_merge_left_flag is equal to 1, SaoEoClass[ 0 ][ rx ][ ry ] is set equal to SaoEoClass[ 0 ][ rx − 1 ][ ry ].

  – Otherwise, if sao_merge_up_flag is equal to 1, SaoEoClass[ 0 ][ rx ][ ry ] is set equal to SaoEoClass[ 0 ][ rx ][ ry − 1 ].

  – Otherwise, SaoEoClass[ 0 ][ rx ][ ry ] is set equal to 0.

**sao_eo_class_chroma** specifies the edge offset class for the chroma components. The values of SaoEoClass[ cIdx ][ rx ][ ry ] are derived as follows for cIdx equal to 1..2:

– If sao_eo_class_chroma is present, SaoEoClass[ cIdx ][ rx ][ ry ] is set equal to sao_eo_class_chroma.

– Otherwise (sao_eo_class_chroma is not present), SaoEoClass[ cIdx ][ rx ][ ry ] is derived as follows:

  – If sao_merge_left_flag is equal to 1, SaoEoClass[ cIdx ][ rx ][ ry ] is set equal to SaoEoClass[ cIdx ][ rx − 1 ][ ry ].

  – Otherwise, if sao_merge_up_flag is equal to 1, SaoEoClass[ cIdx ][ rx ][ ry ] is set equal to SaoEoClass[ cIdx ][ rx ][ ry − 1 ].

  – Otherwise, SaoEoClass[ cIdx ][ rx ][ ry ] is set equal to 0.

**Table 7-9 – Specification of the SAO edge offset class**

| SaoEoClass[ cIdx ][ rx ][ ry ] | SAO edge offset class (informative) |
|---|---|
| 0 | 1D 0-degree edge offset |
| 1 | 1D 90-degree edge offset |
| 2 | 1D 135-degree edge offset |
| 3 | 1D 45-degree edge offset |

#### 7.4.9.4 Coding quadtree semantics

**split_cu_flag**[ x0 ][ y0 ] specifies whether a coding unit is split into coding units with half horizontal and vertical size. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered coding block relative to the top-left luma sample of the picture.

When split_cu_flag[ x0 ][ y0 ] is not present, the following applies:

– If log2CbSize is greater than MinCbLog2SizeY, the value of split_cu_flag[ x0 ][ y0 ] is inferred to be equal to 1.

– Otherwise (log2CbSize is equal to MinCbLog2SizeY), the value of split_cu_flag[ x0 ][ y0 ] is inferred to be equal to 0.

The array CtDepth[ x ][ y ] specifies the coding tree depth for a luma coding block covering the location ( x, y ). When split_cu_flag[ x0 ][ y0 ] is equal to 0, CtDepth[ x ][ y ] is inferred to be equal to cqtDepth for x = x0..x0 + nCbS − 1 and y = y0..y0 + nCbS − 1.

#### 7.4.9.5 Coding unit semantics

**cu_transquant_bypass_flag** equal to 1 specifies that the scaling and transform process as specified in subclause 8.6 and the in-loop filter process as specified in subclause 8.7 are bypassed. When cu_transquant_bypass_flag is not present, it is inferred to be equal to 0.

**cu_skip_flag**[ x0 ][ y0 ] equal to 1 specifies that for the current coding unit, when decoding a P or B slice, no more syntax elements except the merging candidate index merge_idx[ x0 ][ y0 ] are parsed after cu_skip_flag[ x0 ][ y0 ].

cu_skip_flag[ x0 ][ y0 ] equal to 0 specifies that the coding unit is not skipped. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered coding block relative to the top-left luma sample of the picture.

When cu_skip_flag[ x0 ][ y0 ] is not present, it is inferred to be equal to 0.

**pred_mode_flag** equal to 0 specifies that the current coding unit is coded in inter prediction mode. pred_mode_flag equal to 1 specifies that the current coding unit is coded in intra prediction mode. The variable CuPredMode[ x ][ y ] is derived as follows for x = x0..x0 + nCbS − 1 and y = y0..y0 + nCbS − 1:

– If pred_mode_flag is equal to 0, CuPredMode[ x ][ y ] is set equal to MODE_INTER.

– Otherwise (pred_mode_flag is equal to 1), CuPredMode[ x ][ y ] is set equal to MODE_INTRA.

When pred_mode_flag is not present, the variable CuPredMode[ x ][ y ] is derived as follows for x = x0..x0 + nCbS − 1 and y = y0..y0 + nCbS − 1:

– If slice_type is equal to I, CuPredMode[ x ][ y ] is inferred to be equal to MODE_INTRA.

– Otherwise (slice_type is equal to P or B), when cu_skip_flag[ x0 ][ y0 ] is equal to 1, CuPredMode[ x ][ y ] is inferred to be equal to MODE_SKIP.

**part_mode** specifies partitioning mode of the current coding unit. The semantics of part_mode depend on CuPredMode[ x0 ][ y0 ]. The variables PartMode and IntraSplitFlag are derived from the value of part_mode as defined in Table 7-10.

The value of part_mode is restricted as follows:

– If CuPredMode[ x0 ][ y0 ] is equal to MODE_INTRA, part_mode shall be equal to 0 or 1.

– Otherwise (CuPredMode[ x0 ][ y0 ] is equal to MODE_INTER), the following applies:

  – If log2CbSize is greater than MinCbLog2SizeY and amp_enabled_flag is equal to 1, part_mode shall be in the range of 0 to 2, inclusive, or in the range of 4 to 7, inclusive.

  – Otherwise, if log2CbSize is greater than MinCbLog2SizeY and amp_enabled_flag is equal to 0, or log2CbSize is equal to 3, part_mode shall be in the range of 0 to 2, inclusive.

  – Otherwise (log2CbSize is greater than 3 and less than or equal to MinCbLog2SizeY), the value of part_mode shall be in the range of 0 to 3, inclusive.

When part_mode is not present, the variables PartMode and IntraSplitFlag are derived as follows:

– PartMode is set equal to PART_2Nx2N.

– IntraSplitFlag is set equal to 0.

**pcm_flag**[ x0 ][ y0 ] equal to 1 specifies that the pcm_sample( ) syntax structure is present and the transform_tree( ) syntax structure is not present in the coding unit including the luma coding block at the location ( x0, y0 ). pcm_flag[ x0 ][ y0 ] equal to 0 specifies that pcm_sample( ) syntax structure is not present. When pcm_flag[ x0 ][ y0 ] is not present, it is inferred to be equal to 0.

The value of pcm_flag[ x0 + i ][ y0 + j ] with i = 1..nCbS − 1, j = 1..nCbS − 1 is inferred to be equal to pcm_flag[ x0 ][ y0 ].

**pcm_alignment_zero_bit** is a bit equal to 0.

**Table 7-10 – Name association to prediction mode and partitioning type**

| CuPredMode[ x0 ][ y0 ] | part_mode | IntraSplitFlag | PartMode |
|---|---|---|---|
| MODE_INTRA | 0 | 0 | PART_2Nx2N |
| | 1 | 1 | PART_NxN |
| MODE_INTER | 0 | 0 | PART_2Nx2N |
| | 1 | 0 | PART_2NxN |
| | 2 | 0 | PART_Nx2N |
| | 3 | 0 | PART_NxN |
| | 4 | 0 | PART_2NxnU |
| | 5 | 0 | PART_2NxnD |
| | 6 | 0 | PART_nLx2N |
| | 7 | 0 | PART_nRx2N |

The syntax elements **prev_intra_luma_pred_flag**[ x0 + i ][ y0 + j ], **mpm_idx**[ x0 + i ][ y0 + j ] and **rem_intra_luma_pred_mode**[ x0 + i ][ y0 + j ] specify the intra prediction mode for luma samples. The array indices x0 + i, y0 + j specify the location ( x0 + i, y0 + j ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture. When prev_intra_luma_pred_flag[ x0 + i ][ y0 + j ] is equal to 1, the intra prediction mode is inferred from a neighbouring intra-predicted prediction unit according to subclause 8.4.2.

**intra_chroma_pred_mode**[ x0 ][ y0 ] specifies the intra prediction mode for chroma samples. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

**rqt_root_cbf** equal to 1 specifies that the transform_tree( ) syntax structure is present for the current coding unit. rqt_root_cbf equal to 0 specifies that the transform_tree( ) syntax structure is not present for the current coding unit.

When rqt_root_cbf is not present, its value is inferred to be equal to 1.

#### 7.4.9.6 Prediction unit semantics

**mvp_l0_flag**[ x0 ][ y0 ] specifies the motion vector predictor index of list 0 where x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

When mvp_l0_flag[ x0 ][ y0 ] is not present, it is inferred to be equal to 0.

**mvp_l1_flag**[ x0 ][ y0 ] has the same semantics as mvp_l0_flag, with l0 and list 0 replaced by l1 and list 1, respectively.

**merge_flag**[ x0 ][ y0 ] specifies whether the inter prediction parameters for the current prediction unit are inferred from a neighbouring inter-predicted partition. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

When merge_flag[ x0 ][ y0 ] is not present, it is inferred as follows:

– If CuPredMode[ x0 ][ y0 ] is equal to MODE_SKIP, merge_flag[ x0 ][ y0 ] is inferred to be equal to 1.

– Otherwise, merge_flag[ x0 ][ y0 ] is inferred to be equal to 0.

**merge_idx**[ x0 ][ y0 ] specifies the merging candidate index of the merging candidate list where x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

When merge_idx[ x0 ][ y0 ] is not present, it is inferred to be equal to 0.

**inter_pred_idc**[ x0 ][ y0 ] specifies whether list0, list1, or bi-prediction is used for the current prediction unit according to Table 7-11. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

**Table 7-11 – Name association to inter prediction mode**

| inter_pred_idc | Name of inter_pred_idc | |
|---|---|---|
| | ( nPbW + nPbH ) != 12 | ( nPbW + nPbH ) = = 12 |
| 0 | PRED_L0 | PRED_L0 |
| 1 | PRED_L1 | PRED_L1 |
| 2 | PRED_BI | na |

When inter_pred_idc[ x0 ][ y0 ] is not present, it is inferred to be equal to PRED_L0.

**ref_idx_l0**[ x0 ][ y0 ] specifies the list 0 reference picture index for the current prediction unit. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture.

When ref_idx_l0[ x0 ][ y0 ] is not present it is inferred to be equal to 0.

**ref_idx_l1**[ x0 ][ y0 ] has the same semantics as ref_idx_l0, with l0 and list 0 replaced by l1 and list 1, respectively.

### 7.4.9.7 PCM sample semantics

**pcm_sample_luma**[ i ] represents a coded luma sample value in the raster scan within the coding unit. The number of bits used to represent each of these samples is $\text{PcmBitDepth}_Y$.

**pcm_sample_chroma**[ i ] represents a coded chroma sample value in the raster scan within the coding unit. The first half of the values represent coded Cb samples and the remaining half of the values represent coded Cr samples. The number of bits used to represent each of these samples is $\text{PcmBitDepth}_C$.

### 7.4.9.8 Transform tree semantics

**split_transform_flag**[ x0 ][ y0 ][ trafoDepth ] specifies whether a block is split into four blocks with half horizontal and half vertical size for the purpose of transform coding. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered block relative to the top-left luma sample of the picture. The array index trafoDepth specifies the current subdivision level of a coding block into blocks for the purpose of transform coding. trafoDepth is equal to 0 for blocks that correspond to coding blocks.

The variable interSplitFlag is derived as follows:

– If max_transform_hierarchy_depth_inter is equal to 0 and CuPredMode[ x0 ][ y0 ] is equal to MODE_INTER and PartMode is not equal to PART_2Nx2N and trafoDepth is equal to 0, interSplitFlag is set equal to 1.

– Otherwise, interSplitFlag is set equal to 0.

When split_transform_flag[ x0 ][ y0 ][ trafoDepth ] is not present, it is inferred as follows:

– If one or more of the following conditions are true, the value of split_transform_flag[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to 1:
  – log2TrafoSize is greater than Log2MaxTrafoSize
  – IntraSplitFlag is equal to 1 and trafoDepth is equal to 0
  – interSplitFlag is equal to 1
– Otherwise, the value of split_transform_flag[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to 0.

**cbf_luma**[ x0 ][ y0 ][ trafoDepth ] equal to 1 specifies that the luma transform block contains one or more transform coefficient levels not equal to 0. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered transform block relative to the top-left luma sample of the picture. The array index trafoDepth specifies the current subdivision level of a coding block into blocks for the purpose of transform coding. trafoDepth is equal to 0 for blocks that correspond to coding blocks.

When cbf_luma[ x0 ][ y0 ][ trafoDepth ] is not present, it is inferred to be equal to 1.

**cbf_cb**[ x0 ][ y0 ][ trafoDepth ] equal to 1 specifies that the Cb transform block contains one or more transform coefficient levels not equal to 0. The array indices x0, y0 specify the top-left location ( x0, y0 ) of the considered transform unit. The array index trafoDepth specifies the current subdivision level of a coding block into blocks for the purpose of transform coding. trafoDepth is equal to 0 for blocks that correspond to coding blocks.

When cbf_cb[ x0 ][ y0 ][ trafoDepth ] is not present, the value of cbf_cb[ x0 ][ y0 ][ trafoDepth ] is inferred as follows:

– If trafoDepth is greater than 0 and log2TrafoSize is equal to 2, cbf_cb[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to cbf_cb[ xBase ][ yBase ][ trafoDepth − 1 ]

– Otherwise, cbf_cb[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to 0.

**cbf_cr**[ x0 ][ y0 ][ trafoDepth ] equal to 1 specifies that the Cr transform block contains one or more transform coefficient levels not equal to 0. The array indices x0, y0 specify the top-left location ( x0, y0 ) of the considered transform unit. The array index trafoDepth specifies the current subdivision level of a coding block into blocks for the purpose of transform coding. trafoDepth is equal to 0 for blocks that correspond to coding blocks.

When cbf_cr[ x0 ][ y0 ][ trafoDepth ] is not present, the value of cbf_cr[ x0 ][ y0 ][ trafoDepth ] is inferred as follows:

– If trafoDepth is greater than 0 and log2TrafoSize is equal to 2, cbf_cr[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to cbf_cr[ xBase ][ yBase ][ trafoDepth − 1 ]

– Otherwise, cbf_cr[ x0 ][ y0 ][ trafoDepth ] is inferred to be equal to 0.

### 7.4.9.9 Motion vector difference semantics

**abs_mvd_greater0_flag[** compIdx **]** specifies whether the absolute value of a motion vector component difference is greater than 0.

**abs_mvd_greater1_flag[** compIdx **]** specifies whether the absolute value of a motion vector component difference is greater than 1.

When abs_mvd_greater1_flag[ compIdx ] is not present, it is inferred to be equal to 0.

**abs_mvd_minus2[** compIdx **]** plus 2 specifies the absolute value of a motion vector component difference.

When abs_mvd_minus2[ compIdx ] is not present, it is inferred to be equal to −1.

**mvd_sign_flag[** compIdx **]** specifies the sign of a motion vector component difference as follows:

– If mvd_sign_flag[ compIdx ] is equal to 0, the corresponding motion vector component difference has a positive value.

– Otherwise (mvd_sign_flag[ compIdx ] is equal to 1), the corresponding motion vector component difference has a negative value.

When mvd_sign_flag[ compIdx ] is not present, it is inferred to be equal to 0.

The motion vector difference lMvd[ compIdx ] for compIdx = 0..1 is derived as follows:

$$\text{lMvd[ compIdx ]} = \text{abs\_mvd\_greater0\_flag[ compIdx ]} * ( \text{abs\_mvd\_minus2[ compIdx ]} + 2 ) * ( 1 - 2 * \text{mvd\_sign\_flag[ compIdx ]} ) \quad (7\text{-}59)$$

The variable MvdLX[ x0 ][ y0 ][ compIdx ], with X being 0 or 1, specifies the difference between a list X vector component to be used and its prediction. The value of MvdLX[ x0 ][ y0 ][ compIdx ] shall be in the range of $-2^{15}$ to $2^{15} - 1$, inclusive. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered prediction block relative to the top-left luma sample of the picture. The horizontal motion vector component difference is assigned compIdx = 0 and the vertical motion vector component is assigned compIdx = 1.

– If refList is equal to 0, MvdL0[ x0 ][ y0 ][ compIdx ] is set equal to lMvd[ compIdx ] for compIdx = 0..1.

– Otherwise (refList is equal to 1), MvdL1[ x0 ][ y0 ][ compIdx ] is set equal to lMvd[ compIdx ] for compIdx = 0..1.

### 7.4.9.10 Transform unit semantics

The transform coefficient levels are represented by the arrays TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ], which are either specified in subclause 7.3.8.11 or inferred as follows. The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered transform block relative to the top-left luma sample of the picture. The array index cIdx specifies an indicator for the colour component; it is equal to 0 for Y, 1 for Cb, and 2 for Cr. The array indices xC and yC specify the transform coefficient location ( xC, yC ) within the current transform block. When the value of TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ] is not specified in subclause 7.3.8.11, it is inferred to be equal to 0.

**cu_qp_delta_abs** specifies the absolute value of the difference CuQpDeltaVal between the luma quantization parameter of the current coding unit and its prediction.

**cu_qp_delta_sign_flag** specifies the sign of CuQpDeltaVal as follows:

– If cu_qp_delta_sign_flag is equal to 0, the corresponding CuQpDeltaVal has a positive value.

– Otherwise (cu_qp_delta_sign_flag is equal to 1), the corresponding CuQpDeltaVal has a negative value.

When cu_qp_delta_sign_flag is not present, it is inferred to be equal to 0.

When cu_qp_delta_abs is present, the variables IsCuQpDeltaCoded and CuQpDeltaVal are derived as follows:

$$\text{IsCuQpDeltaCoded} = 1 \tag{7-60}$$

$$\text{CuQpDeltaVal} = \text{cu\_qp\_delta\_abs} * ( 1 - 2 * \text{cu\_qp\_delta\_sign\_flag} ) \tag{7-61}$$

The value of CuQpDeltaVal shall be in the range of $-( 26 + \text{QpBdOffset}_Y / 2 )$ to $+( 25 + \text{QpBdOffset}_Y / 2 )$, inclusive.

### 7.4.9.11 Residual coding semantics

For intra prediction, different scanning orders are used. The variable scanIdx specifies which scan order is used where scanIdx equal to 0 specifies an up-right diagonal scan order, scanIdx equal to 1 specifies a horizontal scan order, and scanIdx equal to 2 specifies a vertical scan order. The value of scanIdx is derived as follows:

– If CuPredMode[ x0 ][ y0 ] is equal to MODE_INTRA and one or more of the following conditions are true:
  – log2TrafoSize is equal to 2.
  – log2TrafoSize is equal to 3 and cIdx is equal to 0.

  predModeIntra is derived as follows:
  – If cIdx is equal to 0, predModeIntra is set equal to IntraPredModeY[ x0 ][ y0 ].
  – Otherwise, predModeIntra is set equal to IntraPredModeC.

  scanIdx is derived as follows:
  – If predModeIntra is in the range of 6 to 14, inclusive, scanIdx is set equal to 2.
  – Otherwise if predModeIntra is in the range of 22 to 30, inclusive, scanIdx is set equal to 1.
  – Otherwise, scanIdx is set equal to 0.
– Otherwise, scanIdx is set equal to 0.

**transform_skip_flag**[ x0 ][ y0 ][ cIdx ] specifies whether a transform is applied to the associated transform block or not: The array indices x0, y0 specify the location ( x0, y0 ) of the top-left luma sample of the considered transform block relative to the top-left luma sample of the picture. The array index cIdx specifies an indicator for the colour component; it is equal to 0 for luma, equal to 1 for Cb, and equal to 2 for Cr. transform_skip_flag[ x0 ][ y0 ][ cIdx ] equal to 1 specifies that no transform is applied to the current transform block. transform_skip_flag[ x0 ][ y0 ][ cIdx ] equal to 0 specifies that the decision whether transform is applied to the current transform block or not depends on other syntax elements. When transform_skip_flag[ x0 ][ y0 ][ cIdx ] is not present, it is inferred to be equal to 0.

**last_sig_coeff_x_prefix** specifies the prefix of the column position of the last significant coefficient in scanning order within a transform block. The values of last_sig_coeff_x_prefix shall be in the range of 0 to ( log2TrafoSize << 1 ) − 1, inclusive.

**last_sig_coeff_y_prefix** specifies the prefix of the row position of the last significant coefficient in scanning order within a transform block. The values of last_sig_coeff_y_prefix shall be in the range of 0 to ( log2TrafoSize << 1 ) − 1, inclusive.

**last_sig_coeff_x_suffix** specifies the suffix of the column position of the last significant coefficient in scanning order within a transform block. The values of last_sig_coeff_x_suffix shall be in the range of 0 to ( 1 << ( ( last_sig_coeff_x_prefix >> 1 ) − 1 ) ) − 1, inclusive.

The column position of the last significant coefficient in scanning order within a transform block LastSignificantCoeffX is derived as follows:

– If last_sig_coeff_x_suffix is not present, the following applies:

$$\text{LastSignificantCoeffX} = \text{last\_sig\_coeff\_x\_prefix} \tag{7-62}$$

– Otherwise (last_sig_coeff_x_suffix is present), the following applies:

$$\begin{aligned}\text{LastSignificantCoeffX} = {} & ( 1 \ll ( (\text{last\_sig\_coeff\_x\_prefix} \gg 1 ) - 1 ) ) * \\ & ( 2 + (\text{last\_sig\_coeff\_x\_prefix} \,\&\, 1 ) ) + \text{last\_sig\_coeff\_x\_suffix}\end{aligned} \tag{7-63}$$

**last_sig_coeff_y_suffix** specifies the suffix of the row position of the last significant coefficient in scanning order within a transform block. The values of last_sig_coeff_y_suffix shall be in the range of 0 to ( 1 << ( ( last_sig_coeff_y_prefix >> 1 ) − 1 ) ) − 1, inclusive.

The row position of the last significant coefficient in scanning order within a transform block LastSignificantCoeffY is derived as follows:

– If last_sig_coeff_y_suffix is not present, the following applies:

LastSignificantCoeffY = last_sig_coeff_y_prefix (7-64)

– Otherwise (last_sig_coeff_y_suffix is present), the following applies:

LastSignificantCoeffY = ( 1 << ( ( last_sig_coeff_y_prefix >> 1 ) − 1 ) ) * ( 2 + ( last_sig_coeff_y_prefix & 1 ) ) + last_sig_coeff_y_suffix (7-65)

When scanIdx is equal to 2, the coordinates are swapped as follows:

( LastSignificantCoeffX, LastSignificantCoeffY ) = Swap( LastSignificantCoeffX, LastSignificantCoeffY ) (7-66)

**coded_sub_block_flag**[ xS ][ yS ] specifies the following for the sub-block at location ( xS, yS ) within the current transform block, where a sub-block is a (4x4) array of 16 transform coefficient levels:

– If coded_sub_block_flag[ xS ][ yS ] is equal to 0, the 16 transform coefficient levels of the sub-block at location ( xS, yS ) are inferred to be equal to 0.

– Otherwise (coded_sub_block_flag[ xS ][ yS ] is equal to 1), the following applies:

  – If ( xS, yS ) is equal to ( 0, 0 ) and ( LastSignificantCoeffX, LastSignificantCoeffY ) is not equal to ( 0, 0 ), at least one of the 16 sig_coeff_flag syntax elements is present for the sub-block at location ( xS, yS ) .

  – Otherwise, at least one of the 16 transform coefficient levels of the sub-block at location ( xS, yS ) has a non zero value.

When coded_sub_block_flag[ xS ][ yS ] is not present, it is inferred as follows:

– If one or more of the following conditions are true, coded_sub_block_flag[ xS ][ yS ] is inferred to be equal to 1:

  – ( xS, yS ) is equal to ( 0, 0 )

  – ( xS, yS ) is equal to ( LastSignificantCoeffX >> 2 , LastSignificantCoeffY >> 2 )

– Otherwise, coded_sub_block_flag[ xS ][ yS ] is inferred to be equal to 0.

**sig_coeff_flag[** xC **][** yC **]** specifies for the transform coefficient location ( xC, yC ) within the current transform block whether the corresponding transform coefficient level at the location ( xC, yC ) is non-zero as follows:

– If sig_coeff_flag[ xC ][ yC ] is equal to 0, the transform coefficient level at the location ( xC, yC ) is set equal to 0.

– Otherwise (sig_coeff_flag[ xC ][ yC ] is equal to 1), the transform coefficient level at the location ( xC, yC ) has a non-zero value.

When sig_coeff_flag[ xC ][ yC ] is not present, it is inferred as follows:

– If ( xC, yC ) is the last significant location ( LastSignificantCoeffX, LastSignificantCoeffY ) in scan order or all of the following conditions are true, sig_coeff_flag[ xC ][ yC ] is inferred to be equal to 1:

  – ( xC & 3, yC & 3 ) is equal to ( 0, 0 )

  – inferSbDcSigCoeffFlag is equal to 1

  – coded_sub_block_flag[ xS ][ yS ] is equal to 1

– Otherwise, sig_coeff_flag[ xC ][ yC ] is inferred to be equal to 0.

**coeff_abs_level_greater1_flag[** n **]** specifies for the scanning position n whether there are transform coefficient levels greater than 1.

When coeff_abs_level_greater1_flag[ n ] is not present, it is inferred to be equal to 0.

**coeff_abs_level_greater2_flag[** n **]** specifies for the scanning position n whether there are transform coefficient levels greater than 2.

When coeff_abs_level_greater2_flag[ n ] is not present, it is inferred to be equal to 0.

**coeff_sign_flag[** n **]** specifies the sign of a transform coefficient level for the scanning position n as follows:

– If coeff_sign_flag[ n ] is equal to 0, the corresponding transform coefficient level has a positive value.

– Otherwise (coeff_sign_flag[ n ] is equal to 1), the corresponding transform coefficient level has a negative value.

When coeff_sign_flag[ n ] is not present, it is inferred to be equal to 0.

**coeff_abs_level_remaining[** n **]** is the remaining absolute value of a transform coefficient level that is coded with Golomb-Rice code at the scanning position n. When coeff_abs_level_remaining[ n ] is not present, it is inferred to be equal to 0.

It is a requirement of bitstream conformance that the value of coeff_abs_level_remaining[ n ] shall be constrained such that the corresponding value of TransCoeffLevel[ x0 ][ y0 ][ cIdx ][ xC ][ yC ] is in the range of −32768 to 32767, inclusive.

# 8 Decoding process

## 8.1 General decoding process

Input to this process is a bitstream. Output of this process is a list of decoded pictures.

The layer identifier list TargetDecLayerIdList, which specifies the list of nuh_layer_id values, in increasing order of nuh_layer_id values, of the NAL units to be decoded, is specified as follows:

– If some external means, not specified in this Specification, is available to set TargetDecLayerIdList, TargetDecLayerIdList is set by the external means.

– Otherwise, if the decoding process is invoked in a bitstream conformance test as specified in subclause C.1, TargetDecLayerIdList is set as specified in subclause C.1.

– Otherwise, TargetDecLayerIdList contains only one nuh_layer_id value that is equal to 0.

The variable HighestTid, which identifies the highest temporal sub-layer to be decoded, is specified as follows:

– If some external means, not specified in this Specification, is available to set HighestTid, HighestTid is set by the external means.

– Otherwise, if the decoding process is invoked in a bitstream conformance test as specified in subclause C.1, HighestTid is set as specified in subclause C.1.

– Otherwise, HighestTid is set equal to sps_max_sub_layers_minus1.

The sub-bitstream extraction process as specified in clause 10 is applied with the bitstream, HighestTid, and TargetDecLayerIdList as inputs, and the output is assigned to a bitstream referred to as BitstreamToDecode.

The decoding processes specified in the remainder of this subclause apply to each coded picture, referred to as the current picture and denoted by the variable CurrPic, in BitstreamToDecode.

Depending on the value of chroma_format_idc, the number of sample arrays of the current picture is as follows:

– If chroma_format_idc is equal to 0, the current picture consists of 1 sample array $S_L$.

– Otherwise (chroma_format_idc is not equal to 0), the current picture consists of 3 sample arrays $S_L$, $S_{Cb}$, $S_{Cr}$.

The decoding process for the current picture takes as inputs the syntax elements and upper-case variables from clause 7. When interpreting the semantics of each syntax element in each NAL unit, the term "the bitstream" (or part thereof, e.g. a CVS of the bitstream) refers to BitstreamToDecode (or part thereof).

The decoding process is specified such that all decoders will produce numerically identical cropped decoded pictures. Any decoding process that produces identical cropped decoded pictures to those produced by the process described herein (with the correct output order or output timing, as specified) conforms to the decoding process requirements of this Specification.

When the current picture is a BLA picture that has nal_unit_type equal to BLA_W_LP or is a CRA picture, the following applies:

– If some external means not specified in this Specification is available to set the variable UseAltCpbParamsFlag to a value, UseAltCpbParamsFlag is set equal to the value provided by the external means.

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

When the current picture is an IRAP picture, the following applies:

– If the current picture is an IDR picture, a BLA picture, the first picture in the bitstream in decoding order, or the first picture that follows an end of sequence NAL unit in decoding order, the variable NoRaslOutputFlag is set equal to 1.

– Otherwise, if some external means not specified in this Specification is available to set the variable HandleCraAsBlaFlag to a value for the current picture, the variable HandleCraAsBlaFlag is set equal to the value provided by the external means and the variable NoRaslOutputFlag is set equal to HandleCraAsBlaFlag.

– Otherwise, the variable HandleCraAsBlaFlag is set equal to 0 and the variable NoRaslOutputFlag is set equal to 0.

Depending on the value of separate_colour_plane_flag, the decoding process is structured as follows:

– If separate_colour_plane_flag is equal to 0, the decoding process is invoked a single time with the current picture being the output.

– Otherwise (separate_colour_plane_flag is equal to 1), the decoding process is invoked three times. Inputs to the decoding process are all NAL units of the coded picture with identical value of colour_plane_id. The decoding process of NAL units with a particular value of colour_plane_id is specified as if only a CVS with monochrome colour format with that particular value of colour_plane_id would be present in the bitstream. The output of each of the three decoding processes is assigned to one of the 3 sample arrays of the current picture, with the NAL units with colour_plane_id equal to 0, 1, and 2 being assigned to $S_L$, $S_{Cb}$, and $S_{Cr}$, respectively.

NOTE – The variable ChromaArrayType is derived as equal to 0 when separate_colour_plane_flag is equal to 1 and chroma_format_idc is equal to 3. In the decoding process, the value of this variable is evaluated resulting in operations identical to that of monochrome pictures (when chroma_format_idc is equal to 0).

The decoding process operates as follows for the current picture CurrPic:

1. The decoding of NAL units is specified in subclause 8.2.

2. The processes in subclause 8.3 specify the following decoding processes using syntax elements in the slice segment layer and above:

   – Variables and functions relating to picture order count are derived in subclause 8.3.1. This needs to be invoked only for the first slice segment of a picture.

   – The decoding process for RPS in subclause 8.3.2 is invoked, wherein reference pictures may be marked as "unused for reference" or "used for long-term reference". This needs to be invoked only for the first slice segment of a picture.

   – When the current picture is a BLA picture or is a CRA picture with NoRaslOutputFlag equal to 1, the decoding process for generating unavailable reference pictures specified in subclause 8.3.3 is invoked, which needs to be invoked only for the first slice segment of a picture.

   – PicOutputFlag is set as follows:

     – If the current picture is a RASL picture and NoRaslOutputFlag of the associated IRAP picture is equal to 1, PicOutputFlag is set equal to 0.

     – Otherwise, PicOutputFlag is set equal to pic_output_flag.

   – At the beginning of the decoding process for each P or B slice, the decoding process for reference picture lists construction specified in subclause 8.3.4 is invoked for derivation of reference picture list 0 (RefPicList0) and, when decoding a B slice, reference picture list 1 (RefPicList1).

3. The processes in subclauses 8.4, 8.5, 8.6, and 8.7 specify decoding processes using syntax elements in all syntax structure layers. It is a requirement of bitstream conformance that the coded slices of the picture shall contain slice segment data for every coding tree unit of the picture, such that the division of the picture into slices, the division of the slices into slice segments, and the division of the slice segments into coding tree units each forms a partitioning of the picture.

4. After all slices of the current picture have been decoded, the decoded picture is marked as "used for short-term reference".

## 8.2 NAL unit decoding process

Inputs to this process are NAL units of the access unit containing the current picture.

Outputs of this process are the parsed RBSP syntax structures encapsulated within the NAL units of the access unit containing the current picture.

The decoding process for each NAL unit extracts the RBSP syntax structure from the NAL unit and then parses the RBSP syntax structure.

## 8.3 Slice decoding process

### 8.3.1 Decoding process for picture order count

Output of this process is PicOrderCntVal, the picture order count of the current picture.

Picture order counts are used to identify pictures, for deriving motion parameters in merge mode and motion vector prediction, and for decoder conformance checking (see subclause C.5).

Each coded picture is associated with a picture order count variable, denoted as PicOrderCntVal.

When the current picture is not an IRAP picture with NoRaslOutputFlag equal to 1, the variables prevPicOrderCntLsb and prevPicOrderCntMsb are derived as follows:

– Let prevTid0Pic be the previous picture in decoding order that has TemporalId equal to 0 and that is not a RASL picture, a RADL picture, or a sub-layer non-reference picture.

– The variable prevPicOrderCntLsb is set equal to slice_pic_order_cnt_lsb of prevTid0Pic.

– The variable prevPicOrderCntMsb is set equal to PicOrderCntMsb of prevTid0Pic.

The variable PicOrderCntMsb of the current picture is derived as follows:

– If the current picture is an IRAP picture with NoRaslOutputFlag equal to 1, PicOrderCntMsb is set equal to 0.

– Otherwise, PicOrderCntMsb is derived as follows:

```
if( ( slice_pic_order_cnt_lsb < prevPicOrderCntLsb )  &&
        ( ( prevPicOrderCntLsb − slice_pic_order_cnt_lsb )  >=  ( MaxPicOrderCntLsb / 2 ) ) )
    PicOrderCntMsb = prevPicOrderCntMsb + MaxPicOrderCntLsb                                   (8-1)
else if( (slice_pic_order_cnt_lsb > prevPicOrderCntLsb )  &&
        ( ( slice_pic_order_cnt_lsb − prevPicOrderCntLsb ) > ( MaxPicOrderCntLsb / 2 ) ) )
    PicOrderCntMsb = prevPicOrderCntMsb − MaxPicOrderCntLsb
else
    PicOrderCntMsb = prevPicOrderCntMsb
```

PicOrderCntVal is derived as follows:

PicOrderCntVal = PicOrderCntMsb + slice_pic_order_cnt_lsb (8-2)

NOTE 1 – All IDR pictures will have PicOrderCntVal equal to 0 since slice_pic_order_cnt_lsb is inferred to be 0 for IDR pictures and prevPicOrderCntLsb and prevPicOrderCntMsb are both set equal to 0.

The value of PicOrderCntVal shall be in the range of $-2^{31}$ to $2^{31} - 1$, inclusive. In one CVS, the PicOrderCntVal values for any two coded pictures shall not be the same.

The function PicOrderCnt( picX ) is specified as follows:

PicOrderCnt( picX ) = PicOrderCntVal of the picture picX (8-3)

The function DiffPicOrderCnt( picA, picB ) is specified as follows:

DiffPicOrderCnt( picA, picB ) = PicOrderCnt( picA ) − PicOrderCnt( picB ) (8-4)

The bitstream shall not contain data that result in values of DiffPicOrderCnt( picA, picB ) used in the decoding process that are not in the range of $-2^{15}$ to $2^{15} - 1$, inclusive.

NOTE 2 – Let X be the current picture and Y and Z be two other pictures in the same sequence, Y and Z are considered to be in the same output order direction from X when both DiffPicOrderCnt( X, Y ) and DiffPicOrderCnt( X, Z ) are positive or both are negative.

### 8.3.2 Decoding process for reference picture set

This process is invoked once per picture, after decoding of a slice header but prior to the decoding of any coding unit and prior to the decoding process for reference picture list construction for the slice as specified in subclause 8.3.3. This process may result in one or more reference pictures in the DPB being marked as "unused for reference" or "used for long-term reference".

NOTE 1 – The RPS is an absolute description of the reference pictures used in the decoding process of the current and future coded pictures. The RPS signalling is explicit in the sense that all reference pictures included in the RPS are listed explicitly.

A decoded picture in the DPB can be marked as "unused for reference", "used for short-term reference", or "used for long-term reference", but only one among these three at any given moment during the operation of the decoding process. Assigning one of these markings to a picture implicitly removes another of these markings when applicable. When a picture is referred to as being marked as "used for reference", this collectively refers to the picture being marked as "used for short-term reference" or "used for long-term reference" (but not both).

When the current picture is an IRAP picture with NoRaslOutputFlag equal to 1, all reference pictures currently in the DPB (if any) are marked as "unused for reference".

Short-term reference pictures are identified by their PicOrderCntVal values. Long-term reference pictures are identified either by their PicOrderCntVal values or their slice_pic_order_cnt_lsb values.

Five lists of picture order count values are constructed to derive the RPS. These five lists are PocStCurrBefore, PocStCurrAfter, PocStFoll, PocLtCurr, and PocLtFoll, with NumPocStCurrBefore, NumPocStCurrAfter, NumPocStFoll, NumPocLtCurr, and NumPocLtFoll number of elements, respectively. The five lists and the five variables are derived as follows:

– If the current picture is an IDR picture, PocStCurrBefore, PocStCurrAfter, PocStFoll, PocLtCurr, and PocLtFoll are all set to be empty, and NumPocStCurrBefore, NumPocStCurrAfter, NumPocStFoll, NumPocLtCurr, and NumPocLtFoll are all set equal to 0.

– Otherwise, the following applies:

```
for( i = 0, j = 0, k = 0; i < NumNegativePics[ CurrRpsIdx ] ; i++ )
    if( UsedByCurrPicS0[ CurrRpsIdx ][ i ] )
        PocStCurrBefore[ j++ ] = PicOrderCntVal + DeltaPocS0[ CurrRpsIdx ][ i ]
    else
        PocStFoll[ k++ ] = PicOrderCntVal + DeltaPocS0[ CurrRpsIdx ][ i ]
NumPocStCurrBefore = j

for( i = 0, j = 0; i < NumPositivePics[ CurrRpsIdx ]; i++ )
    if( UsedByCurrPicS1[ CurrRpsIdx ][ i ] )
        PocStCurrAfter[ j++ ] = PicOrderCntVal + DeltaPocS1[ CurrRpsIdx ][ i ]
    else
        PocStFoll[ k++ ] = PicOrderCntVal + DeltaPocS1[ CurrRpsIdx ][ i ]
NumPocStCurrAfter = j
NumPocStFoll = k                                                          (8-5)
for( i = 0, j = 0, k = 0; i < num_long_term_sps + num_long_term_pics; i++ ) {
    pocLt = PocLsbLt[ i ]
    if( delta_poc_msb_present_flag[ i ] )
        pocLt  +=  PicOrderCntVal − DeltaPocMsbCycleLt[ i ] * MaxPicOrderCntLsb − slice_pic_order_cnt_lsb
    if( UsedByCurrPicLt[ i ] ) {
        PocLtCurr[ j ] = pocLt
        CurrDeltaPocMsbPresentFlag[ j++ ] = delta_poc_msb_present_flag[ i ]
    } else {
        PocLtFoll[ k ] = pocLt
        FollDeltaPocMsbPresentFlag[ k++ ] = delta_poc_msb_present_flag[ i ]
    }
}
NumPocLtCurr = j
NumPocLtFoll = k
```

where PicOrderCntVal is the picture order count of the current picture as specified in subclause 8.3.1.

NOTE 2 – A value of CurrRpsIdx in the range of 0 to num_short_term_ref_pic_sets − 1, inclusive, indicates that a candidate short-term RPS from the active SPS is being used, where CurrRpsIdx is the index of the candidate short-term RPS into the list of candidate short-term RPSs signalled in the active SPS. CurrRpsIdx equal to num_short_term_ref_pic_sets indicates that the short-term RPS of the current picture is directly signalled in the slice header.

For each i in the range of 0 to NumPocLtCurr − 1, inclusive, when CurrDeltaPocMsbPresentFlag[ i ] is equal to 1, it is a requirement of bitstream conformance that the following conditions apply:

– There shall be no j in the range of 0 to NumPocStCurrBefore − 1, inclusive, for which PocLtCurr[ i ] is equal to PocStCurrBefore[ j ].

– There shall be no j in the range of 0 to NumPocStCurrAfter − 1, inclusive, for which PocLtCurr[ i ] is equal to PocStCurrAfter[ j ].

– There shall be no j in the range of 0 to NumPocStFoll − 1, inclusive, for which PocLtCurr[ i ] is equal to PocStFoll[ j ].

– There shall be no j in the range of 0 to NumPocLtCurr − 1, inclusive, where j is not equal to i, for which PocLtCurr[ i ] is equal to PocLtCurr[ j ].

For each i in the range of 0 to NumPocLtFoll − 1, inclusive, when FollDeltaPocMsbPresentFlag[ i ] is equal to 1, it is a requirement of bitstream conformance that the following conditions apply:

– There shall be no j in the range of 0 to NumPocStCurrBefore − 1, inclusive, for which PocLtFoll[ i ] is equal to PocStCurrBefore[ j ].

– There shall be no j in the range of 0 to NumPocStCurrAfter − 1, inclusive, for which PocLtFoll[ i ] is equal to PocStCurrAfter[ j ].

– There shall be no j in the range of 0 to NumPocStFoll − 1, inclusive, for which PocLtFoll[ i ] is equal to PocStFoll[ j ].

– There shall be no j in the range of 0 to NumPocLtFoll − 1, inclusive, where j is not equal to i, for which PocLtFoll[ i ] is equal to PocLtFoll[ j ].

– There shall be no j in the range of 0 to NumPocLtCurr − 1, inclusive, for which PocLtFoll[ i ] is equal to PocLtCurr[ j ].

For each i in the range of 0 to NumPocLtCurr − 1, inclusive, when CurrDeltaPocMsbPresentFlag[ i ] is equal to 0, it is a requirement of bitstream conformance that the following conditions apply:

– There shall be no j in the range of 0 to NumPocStCurrBefore − 1, inclusive, for which PocLtCurr[ i ] is equal to ( PocStCurrBefore[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocStCurrAfter − 1, inclusive, for which PocLtCurr[ i ] is equal to ( PocStCurrAfter[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocStFoll − 1, inclusive, for which PocLtCurr[ i ] is equal to ( PocStFoll[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocLtCurr − 1, inclusive, where j is not equal to i, for which PocLtCurr[ i ] is equal to ( PocLtCurr[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

For each i in the range of 0 to NumPocLtFoll − 1, inclusive, when FollDeltaPocMsbPresentFlag[ i ] is equal to 0, it is a requirement of bitstream conformance that the following conditions apply:

– There shall be no j in the range of 0 to NumPocStCurrBefore − 1, inclusive, for which PocLtFoll[ i ] is equal to ( PocStCurrBefore[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocStCurrAfter − 1, inclusive, for which PocLtFoll[ i ] is equal to ( PocStCurrAfter[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocStFoll − 1, inclusive, for which PocLtFoll[ i ] is equal to ( PocStFoll[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocLtFoll − 1, inclusive, where j is not equal to i, for which PocLtFoll[ i ] is equal to ( PocLtFoll[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

– There shall be no j in the range of 0 to NumPocLtCurr − 1, inclusive, for which PocLtFoll[ i ] is equal to ( PocLtCurr[ j ] & ( MaxPicOrderCntLsb − 1 ) ).

The variable NumPocTotalCurr is derived as specified in subclause 7.4.7.2. It is a requirement of bitstream conformance that the following applies to the value of NumPocTotalCurr:

– If the current picture is a BLA or CRA picture, the value of NumPocTotalCurr shall be equal to 0.

– Otherwise, when the current picture contains a P or B slice, the value of NumPocTotalCurr shall not be equal to 0.

The RPS of the current picture consists of five RPS lists; RefPicSetStCurrBefore, RefPicSetStCurrAfter, RefPicSetStFoll, RefPicSetLtCurr and RefPicSetLtFoll. RefPicSetStCurrBefore, RefPicSetStCurrAfter, and RefPicSetStFoll are collectively referred to as the short-term RPS. RefPicSetLtCurr and RefPicSetLtFoll are collectively referred to as the long-term RPS.

NOTE 3 – RefPicSetStCurrBefore, RefPicSetStCurrAfter, and RefPicSetLtCurr contain all reference pictures that may be used for inter prediction of the current picture and one or more pictures that follow the current picture in decoding order. RefPicSetStFoll and RefPicSetLtFoll consist of all reference pictures that are *not* used for inter prediction of the current picture but may be used in inter prediction for one or more pictures that follow the current picture in decoding order.

The derivation process for the RPS and picture marking are performed according to the following ordered steps:

1. The following applies:

```
for( i = 0; i < NumPocLtCurr; i++ )
    if( !CurrDeltaPocMsbPresentFlag[ i ] )
        if( there is a reference picture picX in the DPB with slice_pic_order_cnt_lsb equal to PocLtCurr[ i ] )
            RefPicSetLtCurr[ i ] = picX
        else
            RefPicSetLtCurr[ i ] = "no reference picture"
    else
        if( there is a reference picture picX in the DPB with PicOrderCntVal equal to PocLtCurr[ i ] )
            RefPicSetLtCurr[ i ] = picX
        else
            RefPicSetLtCurr[ i ] = "no reference picture"                                        (8-6)
for( i = 0; i < NumPocLtFoll; i++ )
    if( !FollDeltaPocMsbPresentFlag[ i ] )
        if( there is a reference picture picX in the DPB with slice_pic_order_cnt_lsb equal to PocLtFoll[ i ] )
            RefPicSetLtFoll[ i ] = picX
        else
            RefPicSetLtFoll[ i ] = "no reference picture"
    else
        if( there is a reference picture picX in the DPB with PicOrderCntVal equal to PocLtFoll[ i ] )
            RefPicSetLtFoll[ i ] = picX
        else
            RefPicSetLtFoll[ i ] = "no reference picture"
```

2. All reference pictures that are included in RefPicSetLtCurr and RefPicSetLtFoll are marked as "used for long-term reference".

3. The following applies:

```
for( i = 0; i < NumPocStCurrBefore; i++ )
    if( there is a short-term reference picture picX in the DPB
            with PicOrderCntVal equal to PocStCurrBefore[ i ] )
        RefPicSetStCurrBefore[ i ] = picX
    else
        RefPicSetStCurrBefore[ i ] = "no reference picture"

for( i = 0; i < NumPocStCurrAfter; i++ )
    if( there is a short-term reference picture picX in the DPB
            with PicOrderCntVal equal to PocStCurrAfter[ i ] )
        RefPicSetStCurrAfter[ i ] = picX
    else
        RefPicSetStCurrAfter[ i ] = "no reference picture"                                       (8-7)

for( i = 0; i < NumPocStFoll; i++ )
    if( there is a short-term reference picture picX in the DPB
            with PicOrderCntVal equal to PocStFoll[ i ] )
        RefPicSetStFoll[ i ] = picX
    else
        RefPicSetStFoll[ i ] = "no reference picture"
```

4. All reference pictures in the DPB that are not included in RefPicSetLtCurr, RefPicSetLtFoll, RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetStFoll are marked as "unused for reference".

NOTE 4 – There may be one or more entries in the RPS lists that are equal to "no reference picture" because the corresponding pictures are not present in the DPB. Entries in RefPicSetStFoll or RefPicSetLtFoll that are equal to "no reference picture" should be ignored. An unintentional picture loss should be inferred for each entry in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr that is equal to "no reference picture".

NOTE 5 – A picture cannot be included in more than one of the five RPS lists.

It is a requirement of bitstream conformance that the RPS is restricted as follows:

– There shall be no entry in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr for which one or more of the following are true:

    – The entry is equal to "no reference picture".

  - The entry is a sub-layer non-reference picture and has TemporalId equal to that of the current picture.
  - The entry is a picture that has TemporalId greater than that of the current picture.
- There shall be no entry in RefPicSetLtCurr or RefPicSetLtFoll for which the difference between the picture order count value of the current picture and the picture order count value of the entry is greater than or equal to $2^{24}$.
- When the current picture is a TSA picture, there shall be no picture included in the RPS with TemporalId greater than or equal to the TemporalId of the current picture.
- When the current picture is an STSA picture, there shall be no picture included in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr that has TemporalId equal to that of the current picture.
- When the current picture is a picture that follows, in decoding order, an STSA picture that has TemporalId equal to that of the current picture, there shall be no picture that has TemporalId equal to that of the current picture included in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr that precedes the STSA picture in decoding order.
- When the current picture is a CRA picture, there shall be no picture included in the RPS that precedes, in decoding order, any preceding IRAP picture in decoding order (when present).
- When the current picture is a trailing picture, there shall be no picture in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr that was generated by the decoding process for generating unavailable reference pictures as specified in subclause 8.3.3.
- When the current picture is a trailing picture, there shall be no picture in the RPS that precedes the associated IRAP picture in output order or decoding order.
- When the current picture is a RADL picture, there shall be no picture included in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr that is any of the following:
  - A RASL picture
  - A picture that was generated by the decoding process for generating unavailable reference pictures as specified in subclause 8.3.3
  - A picture that precedes the associated IRAP picture in decoding order
- When the sps_temporal_id_nesting_flag is equal to 1, the following applies:
  - Let tIdA be the value of TemporalId of the current picture picA.
  - Any picture picB with TemporalId equal to tIdB that is less than or equal to tIdA shall not be included in RefPicSetStCurrBefore, RefPicSetStCurrAfter, or RefPicSetLtCurr of picA when there exists a picture picC that has TemporalId less than tIdB, follows picB in decoding order, and precedes picA in decoding order.

### 8.3.3 Decoding process for generating unavailable reference pictures

#### 8.3.3.1 General decoding process for generating unavailable reference pictures

This process is invoked once per coded picture when the current picture is a BLA picture or is a CRA picture with NoRaslOutputFlag equal to 1.

NOTE – This process is primarily specified only for the specification of syntax constraints for RASL pictures. The entire specification of the decoding process for RASL pictures associated with an IRAP picture that has NoRaslOutputFlag equal to 1 is included herein only for purposes of specifying constraints on the allowed syntax content of such RASL pictures. During the decoding process, any RASL pictures associated with an IRAP picture that has NoRaslOutputFlag equal to 1 may be ignored, as these pictures are not specified for output and have no effect on the decoding process of any other pictures that are specified for output. However, in HRD operations as specified in Annex C, RASL access units may need to be taken into consideration in derivation of CPB arrival and removal times.

When this process is invoked, the following applies:

- For each RefPicSetStFoll[ i ], with i in the range of 0 to NumPocStFoll − 1, inclusive, that is equal to "no reference picture", a picture is generated as specified in subclause 8.3.3.2, and the following applies:
  - The value of PicOrderCntVal for the generated picture is set equal to PocStFoll[ i ].
  - The value of PicOutputFlag for the generated picture is set equal to 0.
  - The generated picture is marked as "used for short-term reference".
  - RefPicSetStFoll[ i ] is set to be the generated reference picture.

– For each RefPicSetLtFoll[ i ], with i in the range of 0 to NumPocLtFoll − 1, inclusive, that is equal to "no reference picture", a picture is generated as specified in subclause 8.3.3.2, and the following applies:
  – The value of PicOrderCntVal for the generated picture is set equal to PocLtFoll[ i ].
  – The value of slice_pic_order_cnt_lsb for the generated picture is inferred to be equal to ( PocLtFoll[ i ] & ( MaxPicOrderCntLsb – 1 ) ).
  – The value of PicOutputFlag for the generated picture is set equal to 0.
  – The generated picture is marked as "used for long-term reference".
  – RefPicSetLtFoll[ i ] is set to be the generated reference picture.

#### 8.3.3.2 Generation of one unavailable picture

When this process is invoked, an unavailable picture is generated as follows:

– The value of each element in the sample array $S_L$ for the picture is set equal to $1 \ll ( \text{BitDepth}_Y - 1 )$.
– The value of each element in the sample arrays $S_{Cb}$ and $S_{Cr}$ for the picture is set equal to $1 \ll ( \text{BitDepth}_C - 1 )$.
– The prediction mode CuPredMode[ x ][ y ] is set equal to MODE_INTRA for x = 0..pic_width_in_luma_samples − 1, y = 0..pic_height_in_luma_samples − 1.

### 8.3.4 Decoding process for reference picture lists construction

This process is invoked at the beginning of the decoding process for each P or B slice.

Reference pictures are addressed through reference indices as specified in subclause 8.5.3.3.2. A reference index is an index into a reference picture list. When decoding a P slice, there is a single reference picture list RefPicList0. When decoding a B slice, there is a second independent reference picture list RefPicList1 in addition to RefPicList0.

At the beginning of the decoding process for each slice, the reference picture lists RefPicList0 and, for B slices, RefPicList1 are derived as follows:

The variable NumRpsCurrTempList0 is set equal to Max( num_ref_idx_l0_active_minus1 + 1, NumPocTotalCurr ) and the list RefPicListTemp0 is constructed as follows:

```
rIdx = 0
while( rIdx < NumRpsCurrTempList0 ) {
    for( i = 0; i < NumPocStCurrBefore && rIdx < NumRpsCurrTempList0; rIdx++, i++ )
        RefPicListTemp0[ rIdx ] = RefPicSetStCurrBefore[ i ]
    for( i = 0; i < NumPocStCurrAfter && rIdx < NumRpsCurrTempList0; rIdx++, i++ )        (8-8)
        RefPicListTemp0[ rIdx ] = RefPicSetStCurrAfter[ i ]
    for( i = 0; i < NumPocLtCurr && rIdx < NumRpsCurrTempList0; rIdx++, i++ )
        RefPicListTemp0[ rIdx ] = RefPicSetLtCurr[ i ]
}
```

The list RefPicList0 is constructed as follows:

```
for( rIdx = 0; rIdx <= num_ref_idx_l0_active_minus1; rIdx++)                              (8-9)
    RefPicList0[ rIdx ] = ref_pic_list_modification_flag_l0 ? RefPicListTemp0[ list_entry_l0[ rIdx ] ] :
                                                                 RefPicListTemp0[ rIdx ]
```

When the slice is a B slice, the variable NumRpsCurrTempList1 is set equal to Max( num_ref_idx_l1_active_minus1 + 1, NumPocTotalCurr ) and the list RefPicListTemp1 is constructed as follows:

```
rIdx = 0
while( rIdx < NumRpsCurrTempList1 ) {
    for( i = 0; i < NumPocStCurrAfter && rIdx < NumRpsCurrTempList1; rIdx++, i++ )
        RefPicListTemp1[ rIdx ] = RefPicSetStCurrAfter[ i ]
    for( i = 0; i < NumPocStCurrBefore && rIdx < NumRpsCurrTempList1; rIdx++, i++ )      (8-10)
        RefPicListTemp1[ rIdx ] = RefPicSetStCurrBefore[ i ]
    for( i = 0; i < NumPocLtCurr && rIdx < NumRpsCurrTempList1; rIdx++, i++ )
        RefPicListTemp1[ rIdx ] = RefPicSetLtCurr[ i ]
}
```

When the slice is a B slice, the list RefPicList1 is constructed as follows:

```
for( rIdx = 0; rIdx  <=  num_ref_idx_l1_active_minus1; rIdx++)                                  (8-11)
    RefPicList1[ rIdx ] = ref_pic_list_modification_flag_l1 ? RefPicListTemp1[ list_entry_l1[ rIdx ] ] :
                                                                    RefPicListTemp1[ rIdx ]
```

## 8.4 Decoding process for coding units coded in intra prediction mode

### 8.4.1 General decoding process for coding units coded in intra prediction mode

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current luma coding block.

Output of this process is a modified reconstructed picture before deblocking filtering.

The derivation process for quantization parameters as specified in subclause 8.6.1 is invoked with the luma location ( xCb, yCb ) as input.

A variable nCbS is set equal to 1 << log2CbSize.

Depending on the values of pcm_flag[ xCb ][ yCb ] and IntraSplitFlag, the decoding process for luma samples is specified as follows:

– If pcm_flag[ xCb ][ yCb ] is equal to 1, the reconstructed picture is modified as follows:

$$S_L[\ xCb + i\ ][\ yCb + j\ ] = \text{pcm\_sample\_luma}[\ (\ nCbS * j\ ) + i\ ] \ll (\ BitDepth_Y - PcmBitDepth_Y\ ),\ \text{with } i, j = 0..nCbS - 1 \quad (8\text{-}12)$$

– Otherwise (pcm_flag[ xCb ][ yCb ] is equal to 0), if IntraSplitFlag is equal to 0, the following ordered steps apply:

1. The derivation process for the intra prediction mode as specified in subclause 8.4.2 is invoked with the luma location ( xCb, yCb ) as input.

2. The general decoding process for intra blocks as specified in subclause 8.4.4.1 is invoked with the luma location ( xCb, yCb ), the variable log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable predModeIntra set equal to IntraPredModeY[ xCb ][ yCb ], and the variable cIdx set equal to 0 as inputs, and the output is a modified reconstructed picture before deblocking filtering.

– Otherwise (pcm_flag[ xCb ][ yCb ] is equal to 0 and IntraSplitFlag is equal to 1), for the variable blkIdx proceeding over the values 0..3, the following ordered steps apply:

1. The variable xPb is set equal to xCb + ( nCbS >> 1 ) * ( blkIdx % 2 ).

2. The variable yPb is set equal to yCb + ( nCbS >> 1 ) * ( blkIdx / 2 ).

3. The derivation process for the intra prediction mode as specified in subclause 8.4.2 is invoked with the luma location ( xPb, yPb ) as input.

4. The general decoding process for intra blocks as specified in subclause 8.4.4.1 is invoked with the luma location ( xPb, yPb ), the variable log2TrafoSize set equal to log2CbSize − 1, the variable trafoDepth set equal to 1, the variable predModeIntra set equal to IntraPredModeY[ xPb ][ yPb ], and the variable cIdx set equal to 0 as inputs, and the output is a modified reconstructed picture before deblocking filtering.

Depending on the value of pcm_flag[ xCb ][ yCb ], the decoding process for chroma samples is specified as follows:

– If pcm_flag[ xCb ][ yCb ] is equal to 1, the reconstructed picture is modified as follows:

$$S_{Cb}[\ xCb / 2 + i\ ][\ yCb / 2 + j\ ] = \text{pcm\_sample\_chroma}[\ (\ nCbS / 2 * j\ ) + i\ ] \ll (\ BitDepth_C - PcmBitDepth_C\ ),\ \text{with } i, j = 0..nCbS / 2 - 1 \quad (8\text{-}13)$$

$$S_{Cr}[\ xCb / 2 + i\ ][\ yCb / 2 + j\ ] = \text{pcm\_sample\_chroma}[\ (\ nCbS / 2 * (\ j + nCbS / 2\ )\ ) + i\ ] \ll (\ BitDepth_C - PcmBitDepth_C\ ),\ \text{with } i, j = 0..nCbS / 2 - 1 \quad (8\text{-}14)$$

– Otherwise (pcm_flag[ xCb ][ yCb ] is equal to 0), the following ordered steps apply:

1. The derivation process for the chroma intra prediction mode as specified in 8.4.3 is invoked with the luma location ( xCb, yCb ) as input, and the output is the variable IntraPredModeC.

2. The general decoding process for intra blocks as specified in subclause 8.4.4.1 is invoked with the chroma location ( xCb / 2, yCb / 2 ), the variable log2TrafoSize set equal to log2CbSize − 1, the variable trafoDepth set

equal to 0, the variable predModeIntra set equal to IntraPredModeC, and the variable cIdx set equal to 1 as inputs, and the output is a modified reconstructed picture before deblocking filtering.

3. The general decoding process for intra blocks as specified in subclause 8.4.4.1 is invoked with the chroma location ( xCb / 2, yCb / 2 ), the variable log2TrafoSize set equal to log2CbSize − 1, the variable trafoDepth set equal to 0, the variable predModeIntra set equal to IntraPredModeC, and the variable cIdx set equal to 2 as inputs, and the output is a modified reconstructed picture before deblocking filtering.

### 8.4.2 Derivation process for luma intra prediction mode

Input to this process is a luma location ( xPb, yPb ) specifying the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture.

In this process, the luma intra prediction mode IntraPredModeY[ xPb ][ yPb ] is derived.

Table 8-1 specifies the value for the intra prediction mode and the associated names.

**Table 8-1 – Specification of intra prediction mode and associated names**

| Intra prediction mode | Associated name |
|---|---|
| 0 | INTRA_PLANAR |
| 1 | INTRA_DC |
| 2..34 | INTRA_ANGULAR2..INTRA_ANGULAR34 |

IntraPredModeY[ xPb ][ yPb ] labelled 0..34 represents directions of predictions as illustrated in Figure 8-1.

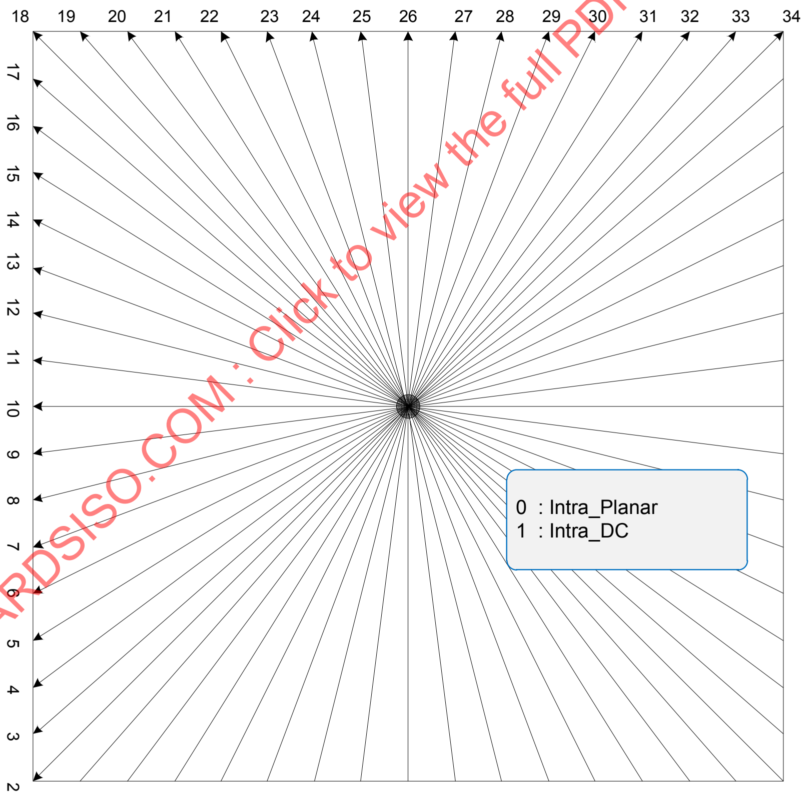


**Figure 8-1 – Intra prediction mode directions (informative)**

IntraPredModeY[ xPb ][ yPb ] is derived by the following ordered steps:

1. The neighbouring locations ( xNbA, yNbA ) and ( xNbB, yNbB ) are set equal to ( xPb − 1, yPb ) and ( xPb, yPb − 1 ), respectively.

2. For X being replaced by either A or B, the variables candIntraPredModeX are derived as follows:

– The availability derivation process for a block in z-scan order as specified in subclause 6.4.1 is invoked with the location ( xCurr, yCurr ) set equal to ( xPb, yPb ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xNbX, yNbX ) as inputs, and the output is assigned to availableX.

– The candidate intra prediction mode candIntraPredModeX is derived as follows:

  – If availableX is equal to FALSE, candIntraPredModeX is set equal to INTRA_DC.

  – Otherwise, if CuPredMode[ xNbX ][ yNbX ] is not equal to MODE_INTRA or pcm_flag[ xNbX ][ yNbX ] is equal to 1, candIntraPredModeX is set equal to INTRA_DC,

  – Otherwise, if X is equal to B and yPb − 1 is less than ( ( yPb >> CtbLog2SizeY ) << CtbLog2SizeY ), candIntraPredModeB is set equal to INTRA_DC.

  – Otherwise, candIntraPredModeX is set equal to IntraPredModeY[ xNbX ][ yNbX ].

3. The candModeList[ x ] with x = 0..2 is derived as follows:

– If candIntraPredModeB is equal to candIntraPredModeA, the following applies:

  – If candIntraPredModeA is less than 2 (i.e. equal to INTRA_PLANAR or INTRA_DC), candModeList[ x ] with x = 0..2 is derived as follows:

    candModeList[ 0 ] = INTRA_PLANAR (8-15)

    candModeList[ 1 ] = INTRA_DC (8-16)

    candModeList[ 2 ] = INTRA_ANGULAR26 (8-17)

  – Otherwise, candModeList[ x ] with x = 0..2 is derived as follows:

    candModeList[ 0 ] = candIntraPredModeA (8-18)

    candModeList[ 1 ] = 2 + ( ( candIntraPredModeA + 29 ) % 32 ) (8-19)

    candModeList[ 2 ] = 2 + ( ( candIntraPredModeA − 2 + 1 ) % 32 ) (8-20)

– Otherwise (candIntraPredModeB is not equal to candIntraPredModeA), the following applies:

  – candModeList[ 0 ] and candModeList[ 1 ] are derived as follows:

    candModeList[ 0 ] = candIntraPredModeA (8-21)

    candModeList[ 1 ] = candIntraPredModeB (8-22)

  – If neither of candModeList[ 0 ] and candModeList[ 1 ] is equal to INTRA_PLANAR, candModeList[ 2 ] is set equal to INTRA_PLANAR,

  – Otherwise, if neither of candModeList[ 0 ] and candModeList[ 1 ] is equal to INTRA_DC, candModeList[ 2 ] is set equal to INTRA_DC,

  – Otherwise, candModeList[ 2 ] is set equal to INTRA_ANGULAR26.

4. IntraPredModeY[ xPb ][ yPb ] is derived by applying the following procedure:

– If prev_intra_luma_pred_flag[ xPb ][ yPb ] is equal to 1, the IntraPredModeY[ xPb ][ yPb ] is set equal to candModeList[ mpm_idx ].

– Otherwise, IntraPredModeY[ xPb ][ yPb ] is derived by applying the following ordered steps:

  1) The array candModeList[ x ], x = 0..2 is modified as the following ordered steps:

    i. When candModeList[ 0 ] is greater than candModeList[ 1 ], both values are swapped as follows:

    ( candModeList[ 0 ], candModeList[ 1 ] ) = Swap( candModeList[ 0 ], candModeList[ 1 ] ) (8-23)

    ii. When candModeList[ 0 ] is greater than candModeList[ 2 ], both values are swapped as follows:

    ( candModeList[ 0 ], candModeList[ 2 ] ) = Swap( candModeList[ 0 ], candModeList[ 2 ] ) (8-24)

    iii. When candModeList[ 1 ] is greater than candModeList[ 2 ], both values are swapped as follows:

    ( candModeList[ 1 ], candModeList[ 2 ] ) = Swap( candModeList[ 1 ], candModeList[ 2 ] ) (8-25)

  2) IntraPredModeY[ xPb ][ yPb ] is derived by the following ordered steps:

    i. IntraPredModeY[ xPb ][ yPb ] is set equal to rem_intra_luma_pred_mode[ xPb ][ yPb ].

ii. For i equal to 0 to 2, inclusive, when IntraPredModeY[ xPb ][ yPb ] is greater than or equal to candModeList[ i ], the value of IntraPredModeY[ xPb ][ yPb ] is incremented by one.

### 8.4.3 Derivation process for chroma intra prediction mode

Input to this process is a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture.

Output of this process is the variable IntraPredModeC.

The chroma intra prediction mode IntraPredModeC is derived using intra_chroma_pred_mode[ xCb ][ yCb ] and IntraPredModeY[ xCb ][ yCb ] as specified in Table 8-2.

**Table 8-2 – Specification of IntraPredModeC**

| **intra_chroma_pred_mode**[ xCb ][ yCb ] | **IntraPredModeY[ xCb ][ yCb ]** | | | | |
|---|---|---|---|---|---|
| | **0** | **26** | **10** | **1** | **X ( 0 <= X <= 34 )** |
| 0 | 34 | 0 | 0 | 0 | 0 |
| 1 | 26 | 34 | 26 | 26 | 26 |
| 2 | 10 | 10 | 34 | 10 | 10 |
| 3 | 1 | 1 | 1 | 34 | 1 |
| 4 | 0 | 26 | 10 | 1 | X |

### 8.4.4 Decoding process for intra blocks

#### 8.4.4.1 General decoding process for intra blocks

Inputs to this process are:

– a sample location ( xTb0, yTb0 ) specifying the top-left sample of the current transform block relative to the top-left sample of the current picture,

– a variable log2TrafoSize specifying the size of the current transform block,

– a variable trafoDepth specifying the hierarchy depth of the current block relative to the coding unit,

– a variable predModeIntra specifying the intra prediction mode,

– a variable cIdx specifying the colour component of the current block.

Output of this process is a modified reconstructed picture before deblocking filtering.

The luma sample location ( xTbY, yTbY ) specifying the top-left sample of the current luma transform block relative to the top-left luma sample of the current picture is derived as follows:

$$( xTbY, yTbY ) = ( cIdx == 0 ) ? ( xTb0, yTb0 ) : ( xTb0 << 1, yTb0 << 1 ) \quad (8-26)$$

The variable splitFlag is derived as follows:

– If cIdx is equal to 0, splitFlag is set equal to split_transform_flag[ xTbY ][ yTbY ][ trafoDepth ].

– Otherwise, if all of the following conditions are true, splitFlag is set equal to 1.

  – cIdx is greater than 0

  – split_transform_flag[ xTbY ][ yTbY ][ trafoDepth ] is equal to 1

  – log2TrafoSize is greater than 2

– Otherwise, splitFlag is set equal to 0.

Depending on the value of splitFlag, the following applies:

– If splitFlag is equal to 1, the following ordered steps apply:

  1. The variables xTb1 and yTb1 are derived as follows:

     – The variable xTb1 is set equal to xTb0 + ( 1 << ( log2TrafoSize − 1 ) ).

– The variable yTb1 is set equal to yTb0 + ( 1 << ( log2TrafoSize − 1 ) ).

2. The general decoding process for intra blocks as specified in this subclause is invoked with the location ( xTb0, yTb0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the intra prediction mode predModeIntra, and the variable cIdx as inputs, and the output is a modified reconstructed picture before deblocking filtering.

3. The general decoding process for intra blocks as specified in this subclause is invoked with the location ( xTb1, yTb0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the intra prediction mode predModeIntra, and the variable cIdx as inputs, and the output is a modified reconstructed picture before deblocking filtering.

4. The general decoding process for intra blocks as specified in this subclause is invoked with the location ( xTb0, yTb1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the intra prediction mode predModeIntra, and the variable cIdx as inputs, and the output is a modified reconstructed picture before deblocking filtering.

5. The general decoding process for intra blocks as specified in this subclause is invoked with the location ( xTb1, yTb1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the intra prediction mode predModeIntra, and the variable cIdx as inputs, and the output is a modified reconstructed picture before deblocking filtering.

– Otherwise (splitFlag is equal to 0), the following ordered steps apply:

1. The variable nTbS is set equal to 1 << log2TrafoSize.

2. The general intra sample prediction process as specified in subclause 8.4.4.2.1 is invoked with the transform block location ( xTb0, yTb0 ), the intra prediction mode predModeIntra, the transform block size nTbS, and the variable cIdx as inputs, and the output is an (nTbS)x(nTbS) array predSamples.

3. The scaling and transformation process as specified in subclause 8.6.2 is invoked with the luma location ( xTbY, yTbY ), the variable trafoDepth, the variable cIdx, and the transform size trafoSize set equal to nTbS as inputs, and the output is an (nTbS)x(nTbS) array resSamples.

4. The picture reconstruction process prior to in-loop filtering for a colour component as specified in subclause 8.6.5 is invoked with the transform block location ( xTb0, yTb0 ), the transform block size nTbS, the variable cIdx, the (nTbS)x(nTbS) array predSamples, and the (nTbS)x(nTbS) array resSamples as inputs.

### 8.4.4.2 Intra sample prediction

#### 8.4.4.2.1 General intra sample prediction

Inputs to this process are:

– a sample location ( xTbCmp, yTbCmp ) specifying the top-left sample of the current transform block relative to the top-left sample of the current picture,

– a variable predModeIntra specifying the intra prediction mode,

– a variable nTbS specifying the transform block size,

– a variable cIdx specifying the colour component of the current block.

Output of this process is the predicted samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1.

The nTbS * 4 + 1 neighbouring samples p[ x ][ y ] that are constructed samples prior to the deblocking filter process, with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1, are derived as follows:

– The neighbouring location ( xNbCmp, yNbCmp ) is specified by:

$$( xNbCmp, yNbCmp ) = ( xTbCmp + x, yTbCmp + y ) \quad (8\text{-}27)$$

– The current luma location ( xTbY, yTbY ) and the neighbouring luma location ( xNbY, yNbY ) are derived as follows:

$$( xTbY, yTbY ) = ( cIdx == 0 ) \mathbin{?} ( xTbCmp, yTbCmp ) : ( xTbCmp << 1, yTbCmp << 1 ) \quad (8\text{-}28)$$

$$( xNbY, yNbY ) = ( cIdx == 0 ) \mathbin{?} ( xNbCmp, yNbCmp ) : ( xNbCmp << 1, yNbCmp << 1 ) \quad (8\text{-}29)$$

– The availability derivation process for a block in z-scan order as specified in subclause 6.4.1 is invoked with the current luma location ( xCurr, yCurr ) set equal to ( xTbY, yTbY ) and the neighbouring luma location ( xNbY, yNbY ) as inputs, and the output is assigned to availableN.

– Each sample p[ x ][ y ] is derived as follows:

  – If one or more of the following conditions are true, the sample p[ x ][ y ] is marked as "not available for intra prediction":

    – The variable availableN is equal to FALSE.

    – CuPredMode[ xNbY ][ yNbY ] is not equal to MODE_INTRA and constrained_intra_pred_flag is equal to 1.

  – Otherwise, the sample p[ x ][ y ] is marked as "available for intra prediction" and the sample at the location ( xNbCmp, yNbCmp ) is assigned to p[ x ][ y ].

When at least one sample p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 is marked as "not available for intra prediction", the reference sample substitution process for intra sample prediction in subclause 8.4.4.2.2 is invoked with the samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1, nTbS, and cIdx as inputs, and the modified samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 as output.

Depending on the value of predModeIntra, the following ordered steps apply:

1. When cIdx is equal to 0, the filtering process of neighbouring samples specified in subclause 8.4.4.2.3 is invoked with the sample array p and the transform block size nTbS as inputs, and the output is reassigned to the sample array p.

2. The intra sample prediction process according to predModeIntra applies as follows:

   – If predModeIntra is equal to INTRA_PLANAR, the corresponding intra prediction mode specified in subclause 8.4.4.2.4 is invoked with the sample array p and the transform block size nTbS as inputs, and the output is the predicted sample array predSamples.

   – Otherwise, if predModeIntra is equal to INTRA_DC, the corresponding intra prediction mode specified in subclause 8.4.4.2.5 is invoked with the sample array p, the transform block size nTbS, and the colour component index cIdx as inputs, and the output is the predicted sample array predSamples.

   – Otherwise (predModeIntra is in the range of INTRA_ANGULAR2..INTRA_ANGULAR34), the corresponding intra prediction mode specified in subclause 8.4.4.2.6 is invoked with the intra prediction mode predModeIntra, the sample array p, the transform block size nTbS, and the colour component index cIdx as inputs, and the output is the predicted sample array predSamples.

### 8.4.4.2.2 Reference sample substitution process for intra sample prediction

Inputs to this process are:

– reference samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 for intra sample prediction,

– a transform block size nTbS,

– a variable cIdx specifying the colour component of the current block.

Outputs of this process are the modified reference samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 for intra sample prediction.

The variable bitDepth is derived as follows:

– If cIdx is equal to 0, bitDepth is set equal to $\text{BitDepth}_Y$.

– Otherwise, bitDepth is set equal to $\text{BitDepth}_C$.

The values of the samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 are modified as follows:

– If all samples p[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 are marked as "not available for intra prediction", the value 1 << ( bitDepth − 1 ) is substituted for the values of all samples p[ x ][ y ].

– Otherwise (at least one but not all samples p[ x ][ y ] are marked as "not available for intra prediction"), the following ordered steps are performed:

  1. When p[ −1 ][ nTbS * 2 − 1 ] is marked as "not available for intra prediction", search sequentially starting from x = −1, y = nTbS * 2 − 1 to x = −1, y = −1, then from x = 0, y = −1 to x = nTbS * 2 − 1, y = −1. Once a sample p[ x ][ y ] marked as "available for intra prediction" is found, the search is terminated and the value of p[ x ][ y ] is assigned to p[ −1 ][ nTbS * 2 − 1 ].

2. Search sequentially starting from $x = -1$, $y = nTbS * 2 - 2$ to $x = -1$, $y = -1$, when p[ x ][ y ] is marked as "not available for intra prediction", the value of p[ x ][ y + 1 ] is substituted for the value of p[ x ][ y ].
3. For $x = 0..nTbS * 2 - 1$, $y = -1$, when p[ x ][ y ] is marked as "not available for intra prediction", the value of p[ x − 1 ][ y ] is substituted for the value of p[ x ][ y ].

All samples p[ x ][ y ] with $x = -1$, $y = -1..nTbS * 2 - 1$ and $x = 0..nTbS * 2 - 1$, $y = -1$ are marked as "available for intra prediction".

### 8.4.4.2.3 Filtering process of neighbouring samples

Inputs to this process are:

– the neighbouring samples p[ x ][ y ], with $x = -1$, $y = -1..nTbS * 2 - 1$ and $x = 0..nTbS * 2 - 1$, $y = -1$,

– a variable nTbS specifying the transform block size.

Outputs of this process are the filtered samples pF[ x ][ y ], with $x = -1$, $y = -1..nTbS * 2 - 1$ and $x = 0..nTbS * 2 - 1$, $y = -1$.

The variable filterFlag is derived as follows:

– If one or more of the following conditions are true, filterFlag is set equal to 0:
  – predModeIntra is equal to INTRA_DC.
  – nTbS is equal 4.
– Otherwise, the following applies:
  – The variable minDistVerHor is set equal to Min( Abs( predModeIntra − 26 ), Abs( predModeIntra − 10 ) ).
  – The variable intraHorVerDistThres[ nTbS ] is specified in Table 8-3.
  – The variable filterFlag is derived as follows:
    – If minDistVerHor is greater than intraHorVerDistThres[ nTbS ], filterFlag is set equal to 1.
    – Otherwise, filterFlag is set equal to 0.

**Table 8-3 – Specification of intraHorVerDistThres[ nTbS ] for various transform block sizes**

| | **nTbS = 8** | **nTbS = 16** | **nTbS = 32** |
|---|---|---|---|
| **intraHorVerDistThres[ nTbS ]** | 7 | 1 | 0 |

When filterFlag is equal to 1, the following applies:

– The variable biIntFlag is derived as follows:
  – If all of the following conditions are true, biIntFlag is set equal to 1:
    – strong_intra_smoothing_enabled_flag is equal to 1
    – nTbS is equal to 32
    – $\text{Abs}( p[ -1 ][ -1 ] + p[ nTbS * 2 - 1 ][ -1 ] - 2 * p[ nTbS - 1 ][ -1 ] ) < ( 1 \ll ( BitDepth_Y - 5 ) )$
    – $\text{Abs}( p[ -1 ][ -1 ] + p[ -1 ][ nTbS * 2 - 1 ] - 2 * p[ -1 ][ nTbS - 1 ] ) < ( 1 \ll ( BitDepth_Y - 5 ) )$
  – Otherwise, biIntFlag is set equal to 0.
– The filtering is performed as follows:
  – If biIntFlag is equal to 1, the filtered sample values pF[ x ][ y ] with $x = -1$, $y = -1..63$ and $x = 0..63$, $y = -1$ are derived as follows:

$$pF[ -1 ][ -1 ] = p[ -1 ][ -1 ] \quad (8\text{-}30)$$

$$pF[ -1 ][ y ] = ( ( 63 - y ) * p[ -1 ][ -1 ] + ( y + 1 ) * p[ -1 ][ 63 ] + 32 ) \gg 6 \text{ for } y = 0..62 \quad (8\text{-}31)$$

$$pF[ -1 ][ 63 ] = p[ -1 ][ 63 ] \quad (8\text{-}32)$$

$$pF[ x ][ -1 ] = ( ( 63 - x ) * p[ -1 ][ -1 ] + ( x + 1 ) * p[ 63 ][ -1 ] + 32 ) \gg 6 \text{ for } x = 0..62 \quad (8\text{-}33)$$

pF[ 63 ][ −1 ] = p[ 63 ][ −1 ] (8-34)

– Otherwise (biIntFlag is equal to 0), the filtered sample values pF[ x ][ y ] with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1 are derived as follows:

pF[ −1 ][ −1 ] = ( p[ −1 ][ 0 ] + 2 * p[ −1 ][ −1 ] + p[ 0 ][ −1 ] + 2 ) >> 2 (8-35)

pF[ −1 ][ y ] = ( p[ −1 ][ y + 1 ] + 2 * p[ −1 ][ y ] + p[ −1 ][ y − 1 ] + 2 ) >> 2 for y = 0..nTbS * 2 − 2 (8-36)

pF[ −1 ][ nTbS * 2 − 1 ] = p[ −1 ][ nTbS * 2 − 1 ] (8-37)

pF[ x ][ −1 ] = ( p[ x − 1 ][ −1 ] + 2 * p[ x ][ −1 ] + p[ x + 1 ][ −1 ] + 2 ) >> 2 for x = 0..nTbS * 2 − 2 (8-38)

pF[ nTbS * 2 − 1 ][ −1 ] = p[ nTbS * 2 − 1 ][ −1 ] (8-39)

### 8.4.4.2.4 Specification of intra prediction mode INTRA_PLANAR

Inputs to this process are:

– the neighbouring samples p[ x ][ y ], with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1,

– a variable nTbS specifying the transform block size.

Outputs of this process are the predicted samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1.

The values of the prediction samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1, are derived as follows:

predSamples[ x ][ y ] = ( ( nTbS − 1 − x ) * p[ −1 ][ y ] + ( x + 1 ) * p[ nTbS ][ −1 ] +
( nTbS − 1 − y ) * p[ x ][ −1 ] +
( y + 1 ) * p[ −1 ][ nTbS ] + nTbS ) >> ( Log2( nTbS ) + 1 ) (8-40)

### 8.4.4.2.5 Specification of intra prediction mode INTRA_DC

Inputs to this process are:

– the neighbouring samples p[ x ][ y ], with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1,

– a variable nTbS specifying the transform block size,

– a variable cIdx specifying the colour component of the current block.

Outputs of this process are the predicted samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1.

The values of the prediction samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1, are derived by the following ordered steps:

1. A variable dcVal is derived as follows:

$$\text{dcVal} = \left( \sum_{x'=0}^{nTbS-1} p[x'][-1] + \sum_{y'=0}^{nTbS-1} p[-1][y'] + nTbS \right) >> (k+1) \quad (8\text{-}41)$$

where k = Log2( nTbS ).

2. Depending on the value of the colour component index cIdx, the following applies:

– If cIdx is equal to 0 and nTbS is less than 32, the following applies:

predSamples[ 0 ][ 0 ] = ( p[ −1 ][ 0 ] + 2 * dcVal + p[ 0 ][ −1 ] + 2 ) >> 2 (8-42)

predSamples[ x ][ 0 ] = ( p[ x ][ −1 ] + 3 * dcVal + 2 ) >> 2, with x = 1..nTbS − 1 (8-43)

predSamples[ 0 ][ y ] = ( p[ −1 ][ y ] + 3 * dcVal + 2 ) >> 2, with y = 1..nTbS − 1 (8-44)

predSamples[ x ][ y ] = dcVal, with x, y = 1..nTbS − 1 (8-45)

– Otherwise, the prediction samples predSamples[ x ][ y ] are derived as follows:

predSamples[ x ][ y ] = dcVal, with x, y = 0..nTbS − 1 (8-46)

### 8.4.4.2.6 Specification of intra prediction mode in the range of INTRA_ANGULAR2.. INTRA_ANGULAR34

Inputs to this process are:

– the intra prediction mode predModeIntra,

– the neighbouring samples p[ x ][ y ], with x = −1, y = −1..nTbS * 2 − 1 and x = 0..nTbS * 2 − 1, y = −1,

– a variable nTbS specifying the transform block size,

– a variable cIdx specifying the colour component of the current block.

Outputs of this process are the predicted samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1.

Figure 8-2 illustrates the total 33 intra angles and Table 8-4 specifies the mapping table between predModeIntra and the angle parameter intraPredAngle.

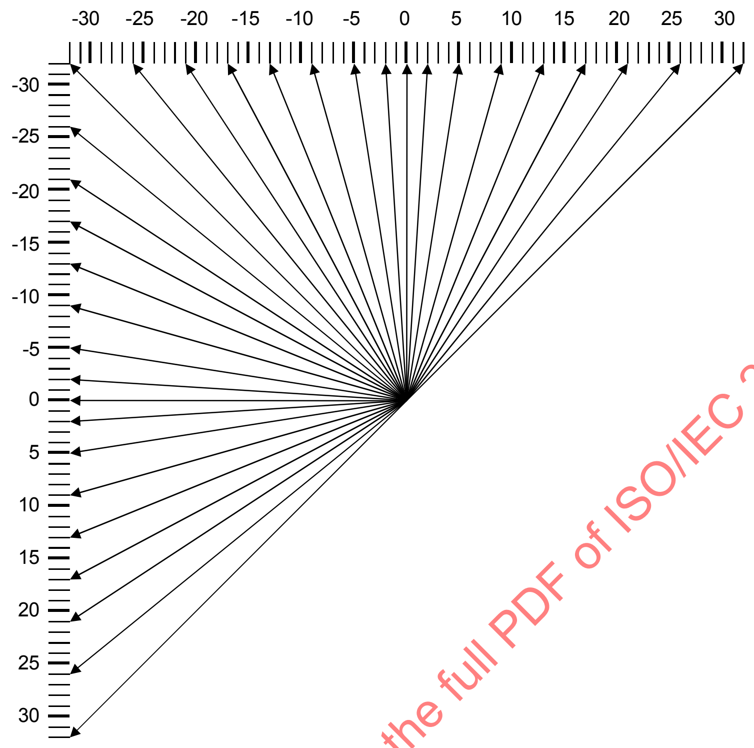


**Figure 8-2 – Intra prediction angle definition (informative)**

**Table 8-4 – Specification of intraPredAngle**

| **predModeIntra** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **intraPredAngle** | - | 32 | 26 | 21 | 17 | 13 | 9 | 5 | 2 | 0 | −2 | −5 | −9 | −13 | −17 | −21 | −26 |
| **predModeIntra** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** |
| **intraPredAngle** | −32 | −26 | −21 | −17 | −13 | −9 | −5 | −2 | 0 | 2 | 5 | 9 | 13 | 17 | 21 | 26 | 32 |

Table 8-5 further specifies the mapping table between predModeIntra and the inverse angle parameter invAngle.

**Table 8-5 – Specification of invAngle**

| **predModeIntra** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** |
|---|---|---|---|---|---|---|---|---|
| **invAngle** | −4096 | −1638 | −910 | −630 | −482 | −390 | −315 | −256 |
| **predModeIntra** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** |
| **invAngle** | −315 | −390 | −482 | −630 | −910 | −1638 | −4096 | - |

The values of the prediction samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1 are derived as follows:

– If predModeIntra is equal or greater than 18, the following ordered steps apply:

1. The reference sample array ref[ x ] is specified as follows:

– The following applies:

$$\text{ref}[\ x\ ] = \text{p}[\ -1 + x\ ][\ -1\ ],\ \text{with } x = 0..\text{nTbS} \qquad (8\text{-}47)$$

– If intraPredAngle is less than 0, the main reference sample array is extended as follows:

– When ( nTbS * intraPredAngle ) >> 5 is less than −1,

$$\text{ref}[\ x\ ] = \text{p}[\ -1\ ][\ -1 + (\ (\ x * \text{invAngle} + 128\ ) \gg 8\ )\ ],\ \text{with } x = -1..(\ \text{nTbS} * \text{intraPredAngle}\ ) \gg 5 \qquad (8\text{-}48)$$

– Otherwise,

$$\text{ref}[\ x\ ] = \text{p}[\ -1 + x\ ][\ -1\ ],\ \text{with } x = \text{nTbS} + 1..2 * \text{nTbS} \qquad (8\text{-}49)$$

2. The values of the prediction samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1 are derived as follows:

a. The index variable iIdx and the multiplication factor iFact are derived as follows:

$$\text{iIdx} = (\ (\ y + 1\ ) * \text{intraPredAngle}\ ) \gg 5 \qquad (8\text{-}50)$$

$$\text{iFact} = (\ (\ y + 1\ ) * \text{intraPredAngle}\ )\ \&\ 31 \qquad (8\text{-}51)$$

b. Depending on the value of iFact, the following applies:

– If iFact is not equal to 0, the value of the prediction samples predSamples[ x ][ y ] is derived as follows:

$$\text{predSamples}[\ x\ ][\ y\ ] = (\ (\ 32 - \text{iFact}\ ) * \text{ref}[\ x + \text{iIdx} + 1\ ] + \text{iFact} * \text{ref}[\ x + \text{iIdx} + 2\ ] + 16\ ) \gg 5 \qquad (8\text{-}52)$$

– Otherwise, the value of the prediction samples predSamples[ x ][ y ] is derived as follows:

$$\text{predSamples}[\ x\ ][\ y\ ] = \text{ref}[\ x + \text{iIdx} + 1\ ] \qquad (8\text{-}53)$$

c. When predModeIntra is equal to 26 (vertical), cIdx is equal to 0 and nTbS is less than 32, the following filtering applies with x = 0, y = 0..nTbS − 1:

$$\text{predSamples}[\ x\ ][\ y\ ] = \text{Clip1}_Y(\ \text{p}[\ x\ ][\ -1\ ] + (\ (\ \text{p}[\ -1\ ][\ y\ ] - \text{p}[\ -1\ ][\ -1\ ]\ ) \gg 1\ )\ ) \qquad (8\text{-}54)$$

– Otherwise (predModeIntra is less than 18), the following ordered steps apply:

1. The reference sample array ref[ x ] is specified as follows:

– The following applies:

$$\text{ref}[\ x\ ] = \text{p}[\ -1\ ][\ -1 + x\ ],\ \text{with } x = 0..\text{nTbS} \qquad (8\text{-}55)$$

– If intraPredAngle is less than 0, the main reference sample array is extended as follows:

– When ( nTbS * intraPredAngle ) >> 5 is less than −1,

$$\text{ref}[\ x\ ] = \text{p}[\ -1 + (\ (\ x * \text{invAngle} + 128\ ) \gg 8\ )\ ][\ -1\ ],\ \text{with } x = -1..(\ \text{nTbS} * \text{intraPredAngle}\ ) \gg 5 \qquad (8\text{-}56)$$

– Otherwise,

$$\text{ref}[\ x\ ] = \text{p}[\ -1\ ][\ -1 + x\ ],\ \text{with } x = \text{nTbS} + 1..2 * \text{nTbS} \qquad (8\text{-}57)$$

2. The values of the prediction samples predSamples[ x ][ y ], with x, y = 0..nTbS − 1 are derived as follows:

a. The index variable iIdx and the multiplication factor iFact are derived as follows:

$$\text{iIdx} = (\ (\ x + 1\ ) * \text{intraPredAngle}\ ) \gg 5 \qquad (8\text{-}58)$$

$$\text{iFact} = (\ (\ x + 1\ ) * \text{intraPredAngle}\ )\ \&\ 31 \qquad (8\text{-}59)$$

b. Depending on the value of iFact, the following applies:

– If iFact is not equal to 0, the value of the prediction samples predSamples[ x ][ y ] is derived as follows:

$$\text{predSamples}[\ x\ ][\ y\ ] = (\ (\ 32 - \text{iFact}\ ) * \text{ref}[\ y + \text{iIdx} + 1\ ] + \text{iFact} * \text{ref}[\ y + \text{iIdx} + 2\ ] + 16\ ) \gg 5 \qquad (8\text{-}60)$$

– Otherwise, the value of the prediction samples predSamples[ x ][ y ] is derived as follows:

$$\text{predSamples}[\ x\ ][\ y\ ] = \text{ref}[\ y + \text{iIdx} + 1\ ] \qquad (8\text{-}61)$$

c. When predModeIntra is equal to 10 (horizontal), cIdx is equal to 0 and nTbS is less than 32, the following filtering applies with x = 0..nTbS − 1, y = 0:

$$predSamples[\ x\ ][\ y\ ] = Clip1_Y(\ p[\ -1\ ][\ y\ ] + (\ (\ p[\ x\ ][\ -1\ ] - p[\ -1\ ][\ -1\ ]\ ) >> 1\ )\ ) \qquad (8\text{-}62)$$

## 8.5 Decoding process for coding units coded in inter prediction mode

### 8.5.1 General decoding process for coding units coded in inter prediction mode

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current coding block.

Output of this process is a modified reconstructed picture before deblocking filtering.

The derivation process for quantization parameters as specified in subclause 8.6.1 is invoked with the luma location ( xCb, yCb ) as input.

The variable $nCbS_L$ is set equal to 1 << log2CbSize and the variable $nCbS_C$ is set equal to 1 << ( log2CbSize − 1 ).

The decoding process for coding units coded in inter prediction mode consists of following ordered steps:

1. The inter prediction process as specified in subclause 8.5.2 is invoked with the luma location ( xCb, yCb ) and the luma coding block size log2CbSize as inputs, and the outputs are three arrays $predSamples_L$, $predSamples_{Cb}$, and $predSamples_{Cr}$.

2. The decoding process for the residual signal of coding units coded in inter prediction mode specified in subclause 8.5.4 is invoked with the luma location ( xCb, yCb ) and the luma coding block size log2CbSize as inputs, and the outputs are three arrays $resSamples_L$, $resSamples_{Cb}$, and $resSamples_{Cr}$.

3. The reconstructed samples of the current coding unit are derived as follows:

   – The picture reconstruction process prior to in-loop filtering for a colour component as specified in subclause 8.6.5 is invoked with the luma coding block location ( xCb, yCb ), the variable nCurrS set equal to $nCbS_L$, the variable cIdx set equal to 0, the $(nCbS_L)$x$(nCbS_L)$ array predSamples set equal to $predSamples_L$, and the $(nCbS_L)$x$(nCbS_L)$ array resSamples set equal to $resSamples_L$ as inputs.

   – The picture reconstruction process prior to in-loop filtering for a colour component as specified in subclause 8.6.5 is invoked with the chroma coding block location ( xCb / 2, yCb / 2 ), the variable nCurrS set equal to $nCbS_C$, the variable cIdx set equal to 1, the $(nCbS_C)$x$(nCbS_C)$ array predSamples set equal to $predSamples_{Cb}$, and the $(nCbS_C)$x$(nCbS_C)$ array resSamples set equal to $resSamples_{Cb}$ as inputs.

   – The picture reconstruction process prior to in-loop filtering for a colour component as specified in subclause 8.6.5 is invoked with the chroma coding block location ( xCb / 2, yCb / 2 ), the variable nCurrS set equal to $nCbS_C$, the variable cIdx set equal to 2, the $(nCbS_C)$x$(nCbS_C)$ array predSamples set equal to $predSamples_{Cr}$, and the $(nCbS_C)$x$(nCbS_C)$ array resSamples set equal to $resSamples_{Cr}$ as inputs.

### 8.5.2 Inter prediction process

This process is invoked when decoding coding unit whose CuPredMode[ xCb ][ yCb ] is not equal to MODE_INTRA.

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current luma coding block.

Outputs of this process are:

– an $(nCbS_L)$x$(nCbS_L)$ array $predSamples_L$ of luma prediction samples, where $nCbS_L$ is derived as specified below,

– an $(nCbS_C)$x$(nCbS_C)$ array $predSamples_{Cb}$ of chroma prediction samples for the component Cb, where $nCbS_C$ is derived as specified below,

– an $(nCbS_C)$x$(nCbS_C)$ array $predSamples_{Cr}$ of chroma prediction samples for the component Cr, where $nCbS_C$ is derived as specified below.

The variable $nCbS_L$ is set equal to 1 << log2CbSize and the variable $nCbS_C$ is set equal to $nCbS_L$ >> 1.

The variable $nCbS1_L$ is set equal to $nCbS_L >> 1$.

Depending on the value of PartMode, the following applies:

– If PartMode is equal to PART_2Nx2N, the decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_2NxN, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to $nCbS_L >> 1$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, $nCbS_L >> 1$ ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to $nCbS_L >> 1$, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and the two modified $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_Nx2N, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L >> 1$, the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( $nCbS_L >> 1$, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L >> 1$, the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and the two modified $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_2NxnU, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to $nCbS_L >> 2$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, $nCbS_L >> 2$ ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to ( $nCbS_L >> 1$ ) + ( $nCbS_L >> 2$ ), and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and the two modified $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_2NxnD, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to ( $nCbS_L >> 1$ ) + ( $nCbS_L >> 2$ ), and a partition index partIdx set equal to 0 as inputs, and the outputs are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, ( $nCbS_L$ >> 1 ) + ( $nCbS_L$ >> 2 ) ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$, the height of the luma prediction block nPbH set equal to $nCbS_L$ >> 2, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and the two modified ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_nLx2N, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 2, the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and two ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( $nCbS_L$ >> 2, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to ( $nCbS_L$ >> 1 ) + ( $nCbS_L$ >> 2 ), the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and the two modified ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise, if PartMode is equal to PART_nRx2N, the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to ( $nCbS_L$ >> 1 ) + ( $nCbS_L$ >> 2 ), the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 0 as inputs, and the outputs are an ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and two ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( $nCS1_L$ + ( $nCbS_L$ >> 2 ), 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 2, the height of the luma prediction block nPbH set equal to $nCbS_L$, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and the two modified ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

– Otherwise (PartMode is equal to PART_NxN), the following ordered steps apply:

1. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 1, the height of the luma prediction block nPbH set equal to $nCbS_L$ >> 1, and a partition index partIdx set equal to 0 as inputs, and the outputs are an ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and two ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

2. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( $nCbS_L$ >> 1, 0 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 1, the height of the luma prediction block nPbH set equal to $nCbS_L$ >> 1, and a partition index partIdx set equal to 1 as inputs, and the outputs are the modified ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and the two modified ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

3. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( 0, $nCbS_L$ >> 1 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 1, the height of the luma prediction block nPbH set equal to $nCbS_L$ >> 1, and a partition index partIdx set equal to 2 as inputs, and the outputs are the modified ($nCbS_L$)x($nCbS_L$) array $predSamples_L$ and the two modified ($nCbS_C$)x($nCbS_C$) arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

4. The decoding process for prediction units in inter prediction mode as specified in subclause 8.5.3 is invoked with the luma location ( xCb, yCb ), the luma location ( xBl, yBl ) set equal to ( $nCbS_L$ >> 1, $nCbS_L$ >> 1 ), the size of the luma coding block $nCbS_L$, the width of the luma prediction block nPbW set equal to $nCbS_L$ >> 1, the height of the luma prediction block nPbH set equal to $nCbS_L$ >> 1, and a partition index

partIdx set equal to 3 as inputs, and the outputs are the modified $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ and the two modified $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cb}$ and $predSamples_{Cr}$.

### 8.5.3 Decoding process for prediction units in inter prediction mode

#### 8.5.3.1 General

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) specifying the top-left sample of the current luma prediction block relative to the top-left sample of the current luma coding block,

– a variable nCbS specifying the size of the current luma coding block,

– a variable nPbW specifying the width of the current luma prediction block,

– a variable nPbH specifying the width of the current luma prediction block,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Outputs of this process are:

– an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ of luma prediction samples, where $nCS_L$ is derived as specified below,

– an $(nCbS_C)x(nCbS_C)$ array $predSamples_{Cb}$ of chroma prediction samples for the component Cb, where $nCS_C$ is derived as specified below,

– an $(nCbS_C)x(nCbS_C)$ array $predSamples_{Cr}$ of chroma prediction samples for the component Cr, where $nCS_C$ is derived as specified below.

The variable $nCbS_L$ is set equal to nCbS and the variable $nCbS_C$ is set equal to nCbS >> 1.

The decoding process for prediction units in inter prediction mode consists of the following ordered steps:

1. The derivation process for motion vector components and reference indices as specified in subclause 8.5.3.2 is invoked with the luma coding block location ( xCb, yCb ), the luma prediction block location ( xBl, yBl ), the luma coding block size block nCbS, the luma prediction block width nPbW, the luma prediction block height nPbH, and the prediction unit index partIdx as inputs, and the luma motion vectors mvL0 and mvL1, the chroma motion vectors mvCL0 and mvCL1, the reference indices refIdxL0 and refIdxL1, and the prediction list utilization flags predFlagL0 and predFlagL1 as outputs.

2. The decoding process for inter sample prediction as specified in subclause 8.5.3.3 is invoked with the luma coding block location ( xCb, yCb ), the luma prediction block location ( xBl, yBl ), the luma coding block size block nCbS, the luma prediction block width nPbW, the luma prediction block height nPbH, the luma motion vectors mvL0 and mvL1, the chroma motion vectors mvCL0 and mvCL1, the reference indices refIdxL0 and refIdxL1, and the prediction list utilization flags predFlagL0 and predFlagL1 as inputs, and the inter prediction samples (predSamples) that are an $(nCbS_L)x(nCbS_L)$ array $predSamples_L$ of prediction luma samples and two $(nCbS_C)x(nCbS_C)$ arrays $predSamples_{Cr}$ and $predSamples_{Cr}$ of prediction chroma samples, one for each of the chroma components Cb and Cr, as outputs.

For use in derivation processes of variables invoked later in the decoding process, the following assignments are made for x = xBl..xBl + nPbW − 1 and y = yBl..yBl + nPbH − 1:

$$MvL0[ xCb + x ][ yCb + y ] = mvL0 \tag{8-63}$$

$$MvL1[ xCb + x ][ yCb + y ] = mvL1 \tag{8-64}$$

$$RefIdxL0[ xCb + x ][ yCb + y ] = refIdxL0 \tag{8-65}$$

$$RefIdxL1[ xCb + x ][ yCb + y ] = refIdxL1 \tag{8-66}$$

$$PredFlagL0[ xCb + x ][ yCb + y ] = predFlagL0 \tag{8-67}$$

$$PredFlagL1[ xCb + x ][ yCb + y ] = predFlagL1 \tag{8-68}$$

#### 8.5.3.2 Derivation process for motion vector components and reference indices

Inputs to this process are:

– a luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) of the top-left sample of the current luma prediction block relative to the top-left sample of the current luma coding block,

– a variable nCbS specifying the size of the current luma coding block,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Outputs of this process are:

– the luma motion vectors mvL0 and mvL1,

– the chroma motion vectors mvCL0 and mvCL1,

– the reference indices refIdxL0 and refIdxL1,

– the prediction list utilization flags predFlagL0 and predFlagL1.

Let ( xPb, yPb ) specify the top-left sample location of the current luma prediction block relative to the top-left luma sample of the current picture where xPb = xCb + xBl and yPb = yCb + yBl.

Let the variable currPic and ListX be the current picture and RefPicListX, with X being 0 or 1, of the current picture, respectively.

The function LongTermRefPic( aPic, aPb, refIdx, LX ), with X being 0 or 1, is defined as follows:

– If the picture with index refIdx from reference picture list LX of the slice containing prediction block aPb in the picture aPic was marked as "used for long term reference" at the time when aPic was the current picture, LongTermRefPic( aPic, aPb, refIdx, LX ) is equal to 1.

– Otherwise, LongTermRefPic( aPic, aPb, refIdx, LX ) is equal to 0.

For the derivation of the variables mvL0 and mvL1, refIdxL0 and refIdxL1, as well as predFlagL0 and predFlagL1, the following applies:

– If merge_flag[ xPb ][ yPb ] is equal to 1, the derivation process for luma motion vectors for merge mode as specified in subclause 8.5.3.2.1 is invoked with the luma location ( xCb, yCb ), the luma location ( xPb, yPb ), the variables nCbS, nPbW, nPbH, and the partition index partIdx as inputs, and the output being the luma motion vectors mvL0, mvL1, the reference indices refIdxL0, refIdxL1, and the prediction list utilization flags predFlagL0 and predFlagL1.

– Otherwise, for X being replaced by either 0 or 1 in the variables predFlagLX, mvLX, and refIdxLX, in PRED_LX, and in the syntax elements ref_idx_lX and MvdLX, the following applies:

  1. The variables refIdxLX and predFlagLX are derived as follows:

     – If inter_pred_idc[ xPb ][ yPb ] is equal to PRED_LX or PRED_BI,

       refIdxLX = ref_idx_lX[ xPb ][ yPb ] (8-69)

       predFlagLX = 1 (8-70)

     – Otherwise, the variables refIdxLX and predFlagLX are specified by:

       refIdxLX = −1 (8-71)

       predFlagLX = 0 (8-72)

  2. The variable mvdLX is derived as follows:

     mvdLX[ 0 ] = MvdLX[ xPb ][ yPb ][ 0 ] (8-73)

     mvdLX[ 1 ] = MvdLX[ xPb ][ yPb ][ 1 ] (8-74)

  3. When predFlagLX is equal to 1, the derivation process for luma motion vector prediction in subclause 8.5.3.2.5 is invoked with the luma coding block location ( xCb, yCb ), the coding block size nCbS, the luma prediction block location ( xPb, yPb ), the variables nPbW, nPbH, refIdxLX, and the partition index partIdx as inputs, and the output being mvpLX.

  4. When predFlagLX is equal to 1, the luma motion vector mvLX is derived as follows:

$$uLX[\ 0\ ] = (\ mvpLX[\ 0\ ] + mvdLX[\ 0\ ] + 2^{16}\ )\ \%\ 2^{16} \tag{8-75}$$

$$mvLX[\ 0\ ] = (\ uLX[\ 0\ ]\ >=\ 2^{15}\ )\ ?\ (\ uLX[\ 0\ ] - 2^{16}\ ) : uLX[\ 0\ ] \tag{8-76}$$

$$uLX[\ 1\ ] = (\ mvpLX[\ 1\ ] + mvdLX[\ 1\ ] + 2^{16}\ )\ \%\ 2^{16} \tag{8-77}$$

$$mvLX[\ 1\ ] = (\ uLX[\ 1\ ]\ >=\ 2^{15}\ )\ ?\ (\ uLX[\ 1\ ] - 2^{16}\ ) : uLX[\ 1\ ] \tag{8-78}$$

NOTE – The resulting values of mvLX[ 0 ] and mvLX[ 1 ] as specified above will always be in the range of $-2^{15}$ to $2^{15} - 1$, inclusive.

When ChromaArrayType is not equal to 0 and predFlagLX, with X being 0 or 1, is equal to 1, the derivation process for chroma motion vectors in subclause 8.5.3.2.9 is invoked with mvLX as input, and the output being mvCLX.

### 8.5.3.2.1 Derivation process for luma motion vectors for merge mode

This process is only invoked when merge_flag[ xPb ][ yPb ] is equal to 1, where ( xPb, yPb ) specify the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture.

Inputs to this process are:

– a luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xPb, yPb ) of the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,

– a variable nCbS specifying the size of the current luma coding block,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Outputs of this process are:

– the luma motion vectors mvL0 and mvL1,

– the reference indices refIdxL0 and refIdxL1,

– the prediction list utilization flags predFlagL0 and predFlagL1.

The location ( xOrigP, yOrigP ) and the variables nOrigPbW and nOrigPbH are derived to store the values of ( xPb, yPb ), nPbW, and nPbH as follows:

$$(\ xOrigP, yOrigP\ ) \text{ is set equal to } (\ xPb, yPb\ ) \tag{8-79}$$

$$nOrigPbW = nPbW \tag{8-80}$$

$$nOrigPbH = nPbH \tag{8-81}$$

When Log2ParMrgLevel is greater than 2 and nCbS is equal to 8, ( xPb, yPb ), nPbW, nPbH, and partIdx are modified as follows:

$$(\ xPb, yPb\ ) = (\ xCb, yCb\ ) \tag{8-82}$$

$$nPbW = nCbS \tag{8-83}$$

$$nPbH = nCbS \tag{8-84}$$

$$partIdx = 0 \tag{8-85}$$

NOTE – When Log2ParMrgLevel is greater than 2 and nCbS is equal to 8, all the prediction units of the current coding unit share a single merge candidate list, which is identical to the merge candidate list of the 2Nx2N prediction unit.

The motion vectors mvL0 and mvL1, the reference indices refIdxL0 and refIdxL1, and the prediction utilization flags predFlagL0 and predFlagL1 are derived by the following ordered steps:

1. The derivation process for merging candidates from neighbouring prediction unit partitions in subclause 8.5.3.2.2 is invoked with the luma coding block location ( xCb, yCb ), the coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, and the partition index partIdx as inputs, and the output being the availability flags $availableFlagA_0$, $availableFlagA_1$, $availableFlagB_0$, $availableFlagB_1$, and $availableFlagB_2$, the reference indices $refIdxLXA_0$, $refIdxLXA_1$, $refIdxLXB_0$, $refIdxLXB_1$, and $refIdxLXB_2$, the prediction list utilization flags $predFlagLXA_0$, $predFlagLXA_1$, $predFlagLXB_0$, $predFlagLXB_1$, and $predFlagLXB_2$, and the motion vectors $mvLXA_0$, $mvLXA_1$, $mvLXB_0$, $mvLXB_1$, and $mvLXB_2$, with X being 0 or 1.

2. The reference indices for the temporal merging candidate, refIdxLXCol, with X being 0 or 1, are set equal to 0.

3. The derivation process for temporal luma motion vector prediction in subclause 8.5.3.2.7 is invoked with the luma location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, and the variable refIdxL0Col as inputs, and the output being the availability flag availableFlagL0Col and the temporal motion vector mvL0Col.The variables availableFlagCol, predFlagL0Col and predFlagL1Col are derived as follows:

   availableFlagCol = availableFlagL0Col (8-86)

   predFlagL0Col = availableFlagL0Col (8-87)

   predFlagL1Col = 0 (8-88)

4. When slice_type is equal to B, the derivation process for temporal luma motion vector prediction in subclause 8.5.3.2.7 is invoked with the luma location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, and the variable refIdxL1Col as inputs, and the output being the availability flag availableFlagL1Col and the temporal motion vector mvL1Col. The variables availableFlagCol and predFlagL1Col are derived as follows:

   availableFlagCol = availableFlagL0Col || availableFlagL1Col (8-89)

   predFlagL1Col = availableFlagL1Col (8-90)

5. The merging candidate list, mergeCandList, is constructed as follows:

```
i = 0
if( availableFlag$A_1$ )
    mergeCandList[ i++ ] = $A_1$
if( availableFlag$B_1$ )
    mergeCandList[ i++ ] = $B_1$
if( availableFlag$B_0$ )
    mergeCandList[ i++ ] = $B_0$                                   (8-91)
if( availableFlag$A_0$ )
    mergeCandList[ i++ ] = $A_0$
if( availableFlag$B_2$ )
    mergeCandList[ i++ ] = $B_2$
if( availableFlagCol )
    mergeCandList[ i++ ] = Col
```

6. The variable numCurrMergeCand and numOrigMergeCand are set equal to the number of merging candidates in the mergeCandList.

7. When slice_type is equal to B, the derivation process for combined bi-predictive merging candidates specified in subclause 8.5.3.2.3 is invoked with mergeCandList, the reference indices refIdxL0N and refIdxL1N, the prediction list utilization flags predFlagL0N and predFlagL1N, the motion vectors mvL0N and mvL1N of every candidate N in mergeCandList, numCurrMergeCand, and numOrigMergeCand as inputs, and the output is assigned to mergeCandList, numCurrMergeCand, the reference indices refIdxL0combCand$_k$ and refIdxL1combCand$_k$, the prediction list utilization flags predFlagL0combCand$_k$ and predFlagL1combCand$_k$, and the motion vectors mvL0combCand$_k$ and mvL1combCand$_k$ of every new candidate combCand$_k$ being added into mergeCandList. The number of candidates being added, numCombMergeCand, is set equal to ( numCurrMergeCand − numOrigMergeCand ). When numCombMergeCand is greater than 0, k ranges from 0 to numCombMergeCand − 1, inclusive.

8. The derivation process for zero motion vector merging candidates specified in subclause 8.5.3.2.4 is invoked with the mergeCandList, the reference indices refIdxL0N and refIdxL1N, the prediction list utilization flags predFlagL0N and predFlagL1N, the motion vectors mvL0N and mvL1N of every candidate N in mergeCandList, and numCurrMergeCand as inputs, and the output is assigned to mergeCandList, numCurrMergeCand, the reference indices refIdxL0zeroCand$_m$ and refIdxL1zeroCand$_m$, the prediction list utilization flags predFlagL0zeroCand$_m$ and predFlagL1zeroCand$_m$, and the motion vectors mvL0zeroCand$_m$ and mvL1zeroCand$_m$ of every new candidate zeroCand$_m$ being added into mergeCandList. The number of candidates being added, numZeroMergeCand, is set equal to ( numCurrMergeCand − numOrigMergeCand − numCombMergeCand ). When numZeroMergeCand is greater than 0, m ranges from 0 to numZeroMergeCand − 1, inclusive.

9. The following assignments are made with N being the candidate at position merge_idx[ xOrigP ][ yOrigP ] in the merging candidate list mergeCandList ( N = mergeCandList[ merge_idx[ xOrigP ][ yOrigP ] ] ) and X being replaced by 0 or 1:

$$\text{mvLX[ 0 ] = mvLXN[ 0 ]} \quad (8\text{-}92)$$

$$\text{mvLX[ 1 ] = mvLXN[ 1 ]} \quad (8\text{-}93)$$

$$\text{refIdxLX = refIdxLXN} \quad (8\text{-}94)$$

$$\text{predFlagLX = predFlagLXN} \quad (8\text{-}95)$$

10. When predFlagL0 is equal to 1 and predFlagL1 is equal to 1, and ( nOrigPbW + nOrigPbH ) is equal to 12, the following applies:

$$\text{refIdxL1} = -1 \quad (8\text{-}96)$$

$$\text{predFlagL1} = 0 \quad (8\text{-}97)$$

#### 8.5.3.2.2 Derivation process for spatial merging candidates

Inputs to this process are:

– a luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable nCbS specifying the size of the current luma coding block,

– a luma location ( xPb, yPb ) specifying the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Outputs of this process are as follows, with X being 0 or 1:

– the availability flags $\text{availableFlagA}_0$, $\text{availableFlagA}_1$, $\text{availableFlagB}_0$, $\text{availableFlagB}_1$, and $\text{availableFlagB}_2$ of the neighbouring prediction units,

– the reference indices $\text{refIdxLXA}_0$, $\text{refIdxLXA}_1$, $\text{refIdxLXB}_0$, $\text{refIdxLXB}_1$, and $\text{refIdxLXB}_2$ of the neighbouring prediction units,

– the prediction list utilization flags $\text{predFlagLXA}_0$, $\text{predFlagLXA}_1$, $\text{predFlagLXB}_0$, $\text{predFlagLXB}_1$, and $\text{predFlagLXB}_2$ of the neighbouring prediction units,

– the motion vectors $\text{mvLXA}_0$, $\text{mvLXA}_1$, $\text{mvLXB}_0$, $\text{mvLXB}_1$, and $\text{mvLXB}_2$ of the neighbouring prediction units.

For the derivation of $\text{availableFlagA}_1$, $\text{refIdxLXA}_1$, $\text{predFlagLXA}_1$, and $\text{mvLXA}_1$ the following applies:

– The luma location ( $\text{xNbA}_1$, $\text{yNbA}_1$ ) inside the neighbouring luma coding block is set equal to ( xPb − 1, yPb + nPbH − 1 ).

– The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( $\text{xNbA}_1$, $\text{yNbA}_1$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $\text{availableA}_1$.

– When one or more of the following conditions are true, $\text{availableA}_1$ is set equal to FALSE:

  – xPb >> Log2ParMrgLevel is equal to $\text{xNbA}_1$ >> Log2ParMrgLevel and yPb >> Log2ParMrgLevel is equal to $\text{yNbA}_1$ >> Log2ParMrgLevel.

  – PartMode of the current prediction unit is equal to PART_Nx2N, PART_nLx2N, or PART_nRx2N, and partIdx is equal to 1.

– The variables $\text{availableFlagA}_1$, $\text{refIdxLXA}_1$, $\text{predFlagLXA}_1$, and $\text{mvLXA}_1$ are derived as follows:

  – If $\text{availableA}_1$ is equal to FALSE, $\text{availableFlagA}_1$ is set equal to 0, both components of $\text{mvLXA}_1$ are set equal to 0, $\text{refIdxLXA}_1$ is set equal to −1 and $\text{predFlagLXA}_1$ is set equal to 0, with X being 0 or 1.

  – Otherwise, $\text{availableFlagA}_1$ is set equal to 1 and the following assignments are made:

$$\text{mvLXA}_1 = \text{MvLX[ xNbA}_1\text{ ][ yNbA}_1\text{ ]} \quad (8\text{-}98)$$

$$\text{refIdxLXA}_1 = \text{RefIdxLX[ xNbA}_1\text{ ][ yNbA}_1\text{ ]} \quad (8\text{-}99)$$

$$\text{predFlagLXA}_1 = \text{PredFlagLX[ xNbA}_1\text{ ][ yNbA}_1\text{ ]} \quad (8\text{-}100)$$

For the derivation of availableFlag$B_1$, refIdxLX$B_1$, predFlagLX$B_1$, and mvLX$B_1$ the following applies:

– The luma location ( xNb$B_1$, yNb$B_1$ ) inside the neighbouring luma coding block is set equal to ( xPb + nPbW − 1, yPb − 1 ).

– The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNb$B_1$, yNb$B_1$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag available$B_1$.

– When one or more of the following conditions are true, available$B_1$ is set equal to FALSE:

  – xPb >> Log2ParMrgLevel is equal to xNb$B_1$ >> Log2ParMrgLevel and yPb >> Log2ParMrgLevel is equal to yNb$B_1$ >> Log2ParMrgLevel.

  – PartMode of the current prediction unit is equal to PART_2NxN, PART_2NxnU, or PART_2NxnD, and partIdx is equal to 1.

– The variables availableFlag$B_1$, refIdxLX$B_1$, predFlagLX$B_1$, and mvLX$B_1$ are derived as follows:

  – If one or more of the following conditions are true, availableFlag$B_1$ is set equal to 0, both components of mvLX$B_1$ are set equal to 0, refIdxLX$B_1$ is set equal to −1, and predFlagLX$B_1$ is set equal to 0, with X being 0 or 1:

    – available$B_1$ is equal to FALSE.

    – available$A_1$ is equal to TRUE and the prediction units covering the luma locations ( xNb$A_1$, yNb$A_1$ ) and ( xNb$B_1$, yNb$B_1$ ) have the same motion vectors and the same reference indices.

  – Otherwise, availableFlag$B_1$ is set equal to 1 and the following assignments are made:

$$\text{mvLXB}_1 = \text{MvLX}[\ \text{xNbB}_1\ ][\ \text{yNbB}_1\ ] \tag{8-101}$$

$$\text{refIdxLXB}_1 = \text{RefIdxLX}[\ \text{xNbB}_1\ ][\ \text{yNbB}_1\ ] \tag{8-102}$$

$$\text{predFlagLXB}_1 = \text{PredFlagLX}[\ \text{xNbB}_1\ ][\ \text{yNbB}_1\ ] \tag{8-103}$$

For the derivation of availableFlag$B_0$, refIdxLX$B_0$, predFlagLX$B_0$, and mvLX$B_0$ the following applies:

– The luma location ( xNb$B_0$, yNb$B_0$ ) inside the neighbouring luma coding block is set equal to ( xPb + nPbW, yPb − 1 ).

– The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNb$B_0$, yNb$B_0$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag available$B_0$.

– When xPb >> Log2ParMrgLevel is equal to xNb$B_0$ >> Log2ParMrgLevel and yPb >> Log2ParMrgLevel is equal to yNb$B_0$ >> Log2ParMrgLevel, available$B_0$ is set equal to FALSE.

– The variables availableFlag$B_0$, refIdxLX$B_0$, predFlagLX$B_0$, and mvLX$B_0$ are derived as follows:

  – If one or more of the following conditions are true, availableFlag$B_0$ is set equal to 0, both components of mvLX$B_0$ are set equal to 0, refIdxLX$B_0$ is set equal to −1, and predFlagLX$B_0$ is set equal to 0, with X being 0 or 1:

    – available$B_0$ is equal to FALSE.

    – available$B_1$ is equal to TRUE and the prediction units covering the luma locations ( xNb$B_1$, yNb$B_1$ ) and ( xNb$B_0$, yNb$B_0$ ) have the same motion vectors and the same reference indices.

  – Otherwise, availableFlag$B_0$ is set equal to 1 and the following assignments are made:

$$\text{mvLXB}_0 = \text{MvLX}[\ \text{xNbB}_0\ ][\ \text{yNbB}_0\ ] \tag{8-104}$$

$$\text{refIdxLXB}_0 = \text{RefIdxLX}[\ \text{xNbB}_0\ ][\ \text{yNbB}_0\ ] \tag{8-105}$$

$$\text{predFlagLXB}_0 = \text{PredFlagLX}[\ \text{xNbB}_0\ ][\ \text{yNbB}_0\ ] \tag{8-106}$$

For the derivation of availableFlag$A_0$, refIdxLX$A_0$, predFlagLX$A_0$, and mvLX$A_0$ the following applies:

- The luma location ( $xNbA_0$, $yNbA_0$ ) inside the neighbouring luma coding block is set equal to ( $xPb - 1$, $yPb + nPbH$ ).
- The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( $xNbA_0$, $yNbA_0$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableA_0$.
- When xPb >> Log2ParMrgLevel is equal to $xNbA_0$ >> Log2ParMrgLevel and yPb >> Log2ParMrgLevel is equal to $yA_0$ >> Log2ParMrgLevel, $availableA_0$ is set equal to FALSE.
- The variables $availableFlagA_0$, $refIdxLXA_0$, $predFlagLXA_0$, and $mvLXA_0$ are derived as follows:
  - If one or more of the following conditions are true, $availableFlagA_0$ is set equal to 0, both components of $mvLXA_0$ are set equal to 0, $refIdxLXA_0$ is set equal to −1, and $predFlagLXA_0$ is set equal to 0, with X being 0 or 1:
    - $availableA_0$ is equal to FALSE.
    - $availableA_1$ is equal to TRUE and the prediction units covering the luma locations ( $xNbA_1$, $yNbA_1$ ) and ( $xNbA_0$, $yNbA_0$ ) have the same motion vectors and the same reference indices.
  - Otherwise, $availableFlagA_0$ is set equal to 1 and the following assignments are made:

$$mvLXA_0 = MvLX[\ xNbA_0\ ][\ yNbA_0\ ] \tag{8-107}$$

$$refIdxLXA_0 = RefIdxLX[\ xNbA_0\ ][\ yNbA_0\ ] \tag{8-108}$$

$$predFlagLXA_0 = PredFlagLX[\ xNbA_0\ ][\ yNbA_0\ ] \tag{8-109}$$

For the derivation of $availableFlagB_2$, $refIdxLXB_2$, $predFlagLXB_2$, and $mvLXB_2$ the following applies:

- The luma location ( $xNbB_2$, $yNbB_2$ ) inside the neighbouring luma coding block is set equal to ( $xPb - 1$, $yPb - 1$ ).
- The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( $xNbB_2$, $yNbB_2$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableB_2$.
- When xPb >> Log2ParMrgLevel is equal to $xNbB_2$ >> Log2ParMrgLevel and yPb >> Log2ParMrgLevel is equal to $yNbB_2$ >> Log2ParMrgLevel, $availableB_2$ is set equal to FALSE.
- The variables $availableFlagB_2$, $refIdxLXB_2$, $predFlagLXB_2$, and $mvLXB_2$ are derived as follows:
  - If one or more of the following conditions are true, $availableFlagB_2$ is set equal to 0, both components of $mvLXB_2$ are set equal to 0, $refIdxLXB_2$ is set equal to −1, and $predFlagLXB_2$ is set equal to 0, with X being 0 or 1:
    - $availableB_2$ is equal to FALSE.
    - $availableA_1$ is equal to TRUE and prediction units covering the luma locations ( $xNbA_1$, $yNbA_1$ ) and ( $xNbB_2$, $yNbB_2$ ) have the same motion vectors and the same reference indices.
    - $availableB_1$ is equal to TRUE and the prediction units covering the luma locations ( $xNbB_1$, $yNbB_1$ ) and ( $xNbB_2$, $yNbB_2$ ) have the same motion vectors and the same reference indices.
    - $availableFlagA_0 + availableFlagA_1 + availableFlagB_0 + availableFlagB_1$ is equal to 4.
  - Otherwise, $availableFlagB_2$ is set equal to 1, and the following assignments are made:

$$mvLXB_2 = MvLX[\ xNbB_2\ ][\ yNbB_2\ ] \tag{8-110}$$

$$refIdxLXB_2 = RefIdxLX[\ xNbB_2\ ][\ yNbB_2\ ] \tag{8-111}$$

$$predFlagLXB_2 = PredFlagLX[\ xNbB_2\ ][\ yNbB_2\ ] \tag{8-112}$$

### 8.5.3.2.3 Derivation process for combined bi-predictive merging candidates

Inputs to this process are:

- a merging candidate list mergeCandList,

– the reference indices refIdxL0N and refIdxL1N of every candidate N in mergeCandList,

– the prediction list utilization flags predFlagL0N and predFlagL1N of every candidate N in mergeCandList,

– the motion vectors mvL0N and mvL1N of every candidate N in mergeCandList,

– the number of elements numCurrMergeCand within mergeCandList,

– the number of elements numOrigMergeCand within the mergeCandList after the spatial and temporal merge candidate derivation process.

Outputs of this process are:

– the merging candidate list mergeCandList,

– the number of elements numCurrMergeCand within mergeCandList,

– the reference indices refIdxL0combCand$_k$ and refIdxL1combCand$_k$ of every new candidate combCand$_k$ added into mergeCandList during the invokation of this process,

– the prediction list utilization flags predFlagL0combCand$_k$ and predFlagL1combCand$_k$ of every new candidate combCand$_k$ added into mergeCandList during the invokation of this process,

– the motion vectors mvL0combCand$_k$ and mvL1combCand$_k$ of every new candidate combCand$_k$ added into mergeCandList during the invokation of this process.

When numOrigMergeCand is greater than 1 and less than MaxNumMergeCand, the variable numInputMergeCand is set equal to numCurrMergeCand, the variable combIdx is set equal to 0, the variable combStop is set equal to FALSE, and the following steps are repeated until combStop is equal to TRUE:

1. The variables l0CandIdx and l1CandIdx are derived using combIdx as specified in Table 8-6.

2. The following assignments are made, with l0Cand being the candidate at position l0CandIdx and l1Cand being the candidate at position l1CandIdx in the merging candidate list mergeCandList:

   – l0Cand = mergeCandList[ l0CandIdx ]

   – l1Cand = mergeCandList[ l1CandIdx ]

3. When all of the following conditions are true:

   – predFlagL0l0Cand = = 1

   – predFlagL1l1Cand = = 1

   – ( DiffPicOrderCnt( RefPicList0[ refIdxL0l0Cand ], RefPicList1[ refIdxL1l1Cand ] ) != 0 ) | | ( mvL0l0Cand != mvL1l1Cand )

   the candidate combCand$_k$ with k equal to ( numCurrMergeCand − numInputMergeCand ) is added at the end of mergeCandList, i.e. mergeCandList[ numCurrMergeCand ] is set equal to combCand$_k$, and the reference indices, the prediction list utilization flags, and the motion vectors of combCand$_k$ are derived as follows and numCurrMergeCand is incremented by 1:

   refIdxL0combCand$_k$ = refIdxL0l0Cand (8-113)

   refIdxL1combCand$_k$ = refIdxL1l1Cand (8-114)

   predFlagL0combCand$_k$ = 1 (8-115)

   predFlagL1combCand$_k$ = 1 (8-116)

   mvL0combCand$_k$[ 0 ] = mvL0l0Cand[ 0 ] (8-117)

   mvL0combCand$_k$[ 1 ] = mvL0l0Cand[ 1 ] (8-118)

   mvL1combCand$_k$[ 0 ] = mvL1l1Cand[ 0 ] (8-119)

   mvL1combCand$_k$[ 1 ] = mvL1l1Cand[ 1 ] (8-120)

   numCurrMergeCand = numCurrMergeCand + 1 (8-121)

4. The variable combIdx is incremented by 1.

5. When combIdx is equal to ( numOrigMergeCand * ( numOrigMergeCand − 1 ) ) or numCurrMergeCand is equal to MaxNumMergeCand, combStop is set equal to TRUE.

**Table 8-6 – Specification of l0CandIdx and l1CandIdx**

| combIdx | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| l0CandIdx | 0 | 1 | 0 | 2 | 1 | 2 | 0 | 3 | 1 | 3 | 2 | 3 |
| l1CandIdx | 1 | 0 | 2 | 0 | 2 | 1 | 3 | 0 | 3 | 1 | 3 | 2 |

### 8.5.3.2.4 Derivation process for zero motion vector merging candidates

Inputs to this process are:

– a merging candidate list mergeCandList,

– the reference indices refIdxL0N and refIdxL1N of every candidate N in mergeCandList,

– the prediction list utilization flags predFlagL0N and predFlagL1N of every candidate N in mergeCandList,

– the motion vectors mvL0N and mvL1N of every candidate N in mergeCandList,

– the number of elements numCurrMergeCand within mergeCandList.

Outputs of this process are:

– the merging candidate list mergeCandList,

– the number of elements numCurrMergeCand within mergeCandList,

– the reference indices $\text{refIdxL0zeroCand}_m$ and $\text{refIdxL10zeroCand}_m$ of every new candidate $\text{zeroCand}_m$ added into mergeCandList during the invokation of this process,

– the prediction list utilization flags $\text{predFlagL0zeroCand}_m$ and $\text{predFlagL10zeroCand}_m$ of every new candidate $\text{zeroCand}_m$ added into mergeCandList during the invokation of this process,

– the motion vectors $\text{mvL0zeroCand}_m$ and $\text{mvL10zeroCand}_m$ of every new candidate $\text{zeroCand}_m$ added into mergeCandList during the invokation of this process.

The variable numRefIdx is derived as follows:

– If slice_type is equal to P, numRefIdx is set equal to num_ref_idx_l0_active_minus1 + 1.

– Otherwise (slice_type is equal to B), numRefIdx is set equal to Min( num_ref_idx_l0_active_minus1 + 1, num_ref_idx_l1_active_minus1 + 1 ).

When numCurrMergeCand is less than MaxNumMergeCand, the variable numInputMergeCand is set equal to numCurrMergeCand, the variable zeroIdx is set equal to 0, and the following steps are repeated until numCurrMergeCand is equal to MaxNumMergeCand:

1. For the derivation of the reference indices, the prediction list utilization flags and the motion vectors of the zero motion vector merging candidate, the following applies:

   – If slice_type is equal to P, the candidate $\text{zeroCand}_m$ with m equal to ( numCurrMergeCand − numInputMergeCand ) is added at the end of mergeCandList, i.e. mergeCandList[ numCurrMergeCand ] is set equal to $\text{zeroCand}_m$, and the reference indices, the prediction list utilization flags, and the motion vectors of $\text{zeroCand}_m$ are derived as follows and numCurrMergeCand is incremented by 1:

$$\text{refIdxL0zeroCand}_m = (\text{ zeroIdx} < \text{numRefIdx} ) \text{ ? zeroIdx : } 0 \quad (8\text{-}122)$$

$$\text{refIdxL1zeroCand}_m = -1 \quad (8\text{-}123)$$

$$\text{predFlagL0zeroCand}_m = 1 \quad (8\text{-}124)$$

$$\text{predFlagL1zeroCand}_m = 0 \quad (8\text{-}125)$$

$$\text{mvL0zeroCand}_m[\ 0\ ] = 0 \quad (8\text{-}126)$$

$$\text{mvL0zeroCand}_m[\ 1\ ] = 0 \quad (8\text{-}127)$$

$$\text{mvL1zeroCand}_m[\ 0\ ] = 0 \quad (8\text{-}128)$$

$$\text{mvL1zeroCand}_m[\ 1\ ] = 0 \quad (8\text{-}129)$$

numCurrMergeCand = numCurrMergeCand + 1 (8-130)

– Otherwise (slice_type is equal to B), the candidate $\text{zeroCand}_m$ with m equal to ( numCurrMergeCand − numInputMergeCand ) is added at the end of mergeCandList, i.e. mergeCandList[ numCurrMergeCand ] is set equal to $\text{zeroCand}_m$, and the reference indices, the prediction list utilization flags, and the motion vectors of $\text{zeroCand}_m$ are derived as follows and numCurrMergeCand is incremented by 1:

$\text{refIdxL0zeroCand}_m = ( \text{zeroIdx} < \text{numRefIdx} ) \ ? \ \text{zeroIdx} : 0$ (8-131)

$\text{refIdxL1zeroCand}_m = ( \text{zeroIdx} < \text{numRefIdx} ) \ ? \ \text{zeroIdx} : 0$ (8-132)

$\text{predFlagL0zeroCand}_m = 1$ (8-133)

$\text{predFlagL1zeroCand}_m = 1$ (8-134)

$\text{mvL0zeroCand}_m[ 0 ] = 0$ (8-135)

$\text{mvL0zeroCand}_m[ 1 ] = 0$ (8-136)

$\text{mvL1zeroCand}_m[ 0 ] = 0$ (8-137)

$\text{mvL1zeroCand}_m[ 1 ] = 0$ (8-138)

numCurrMergeCand = numCurrMergeCand + 1 (8-139)

2. The variable zeroIdx is incremented by 1.

### 8.5.3.2.5 Derivation process for luma motion vector prediction

Inputs to this process are:

– a luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable nCbS specifying the size of the current luma coding block,

– a luma location ( xPb, yPb ) specifying the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– the reference index of the current prediction unit partition refIdxLX, with X being 0 or 1,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Output of this process is the prediction mvpLX of the motion vector mvLX, with X being 0 or 1.

The motion vector predictor mvpLX is derived in the following ordered steps:

1. The derivation process for motion vector predictor candidates from neighbouring prediction unit partitions in subclause 8.5.3.2.6 is invoked with the luma coding block location ( xCb, yCb ), the coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, refIdxLX, with X being 0 or 1, and the partition index partIdx as inputs, and the availability flags availableFlagLXN and the motion vectors mvLXN, with N being replaced by A or B, as output.

2. If both availableFlagLXA and availableFlagLXB are equal to 1 and mvLXA is not equal to mvLXB, availableFlagLXCol is set equal to 0. Otherwise, the derivation process for temporal luma motion vector prediction in subclause 8.5.3.2.7 is invoked with luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, and refIdxLX, with X being 0 or 1, as inputs, and with the output being the availability flag availableFlagLXCol and the temporal motion vector predictor mvLXCol.

3. The motion vector predictor candidate list, mvpListLX, is constructed as follows:

```
i = 0
if( availableFlagLXA )
    mvpListLX[ i++ ] = mvLXA
if( availableFlagLXB )
    mvpListLX[ i++ ] = mvLXB                                   (8-140)
if( availableFlagLXCol )
    mvpListLX[ i++ ] = mvLXCol
```

4. The motion vector predictor list is modified as follows:

– When mvLXA and mvLXB have the same value, mvLXB is removed from the list and the variable numMvpCandLX is set equal to the number of elements within the mvpListLX.

– When numMvpCandLX is less than 2, the following applies repeatedly until numMvpCandLX is equal to 2:

mvpListLX[ numMvpCandLX ][ 0 ] = 0 (8-141)

mvpListLX[ numMvpCandLX ][ 1 ] = 0 (8-142)

numMvpCandLX = numMvpCandLX + 1 (8-143)

– When numMvpCandLX is greater than 2, all motion vector predictor candidates mvpListLX[ idx ] with idx greater than 1 are removed from the list.

5. The motion vector of mvpListLX[ mvp_lX_flag[ xPb ][ yPb ] ] is assigned to mvpLX.

### 8.5.3.2.6 Derivation process for motion vector predictor candidates

Inputs to this process are:

– a luma location ( xCb, yCb ) of the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable nCbS specifying the size of the current luma coding block,

– a luma location ( xPb, yPb ) specifying the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– the reference index of the current prediction unit partition refIdxLX, with X being 0 or 1,

– a variable partIdx specifying the index of the current prediction unit within the current coding unit.

Outputs of this process are (with N being replaced by A or B):

– the motion vectors mvLXN of the neighbouring prediction units,

– the availability flags availableFlagLXN of the neighbouring prediction units.

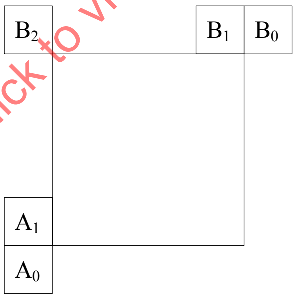


**Figure 8-3 – Spatial motion vector neighbours (informative)**

The variable currPb specifies the current luma prediction block at luma location ( xPb, yPb ) and the variable currPic specifies the current picture.

The variable isScaledFlagLX, with X being 0 or 1, is set equal to 0.

The motion vector mvLXA and the availability flag availableFlagLXA are derived in the following ordered steps:

1. The sample location ( $xNbA_0$, $yNbA_0$ ) is set equal to ( xPb − 1, yPb + nPbH ) and the sample location ( $xNbA_1$, $yNbA_1$ ) is set equal to ( $xNbA_0$, $yNbA_0$ − 1 ).

2. The availability flag availableFlagLXA is set equal to 0 and both components of mvLXA are set equal to 0.

3. The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNbY, yNbY ) set equal to ( $xNbA_0$, $yNbA_0$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableA_0$.

4. The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNbY, yNbY ) set equal to ( $xNbA_1$, $yNbA_1$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableA_1$.

5. When $availableA_0$ or $availableA_1$ is equal to TRUE, the variable isScaledFlagLX is set equal to 1.

6. The following applies for ( $xNbA_k$, $yNbA_k$ ) from ( $xNbA_0$, $yNbA_0$ ) to ( $xNbA_1$, $yNbA_1$ ):

   – When $availableA_k$ is equal to TRUE and availableFlagLXA is equal to 0, the following applies:

     – If PredFlagLX[ $xNbA_k$ ][ $yNbA_k$ ] is equal to 1 and DiffPicOrderCnt( RefPicListX[ RefIdxLX[ $xNbA_k$ ][ $yNbA_k$ ] ], RefPicListX[ refIdxLX ] ) is equal to 0, availableFlagLXA is set equal to 1 and the following applies:

       mvLXA = MvLX[ $xNbA_k$ ][ $yNbA_k$ ] (8-144)

     – Otherwise, when PredFlagLY[ $xNbA_k$ ][ $yNbA_k$ ] (with Y = !X) is equal to 1 and DiffPicOrderCnt( RefPicListY[ RefIdxLY[ $xNbA_k$ ][ $yNbA_k$ ] ], RefPicListX[ refIdxLX ] ) is equal to 0, availableFlagLXA is set equal to 1 and the following applies:

       mvLXA = MvLY[ $xNbA_k$ ][ $yNbA_k$ ] (8-145)

7. When availableFlagLXA is equal to 0, the following applies for ( $xNbA_k$, $yNbA_k$ ) from ( $xNbA_0$, $yNbA_0$ ) to ( $xNbA_1$, $yNbA_1$ ) or until availableFlagLXA is equal to 1:

   – When $availableA_k$ is equal to TRUE and availableFlagLXA is equal to 0, the following applies:

     – If PredFlagLX[ $xNbA_k$ ][ $yNbA_k$ ] is equal to 1 and LongTermRefPic( currPic, currPb, refIdxLX, RefPicListX ) is equal to LongTermRefPic( currPic, currPb, RefIdxLX[ $xNbA_k$ ][ $yNbA_k$ ], RefPicListX ), availableFlagLXA is set equal to 1 and the following assignments are made:

       mvLXA = MvLX[ $xNbA_k$ ][ $yNbA_k$ ] (8-146)

       refIdxA = RefIdxLX[ $xNbA_k$ ][ $yNbA_k$ ] (8-147)

       refPicListA = RefPicListX (8-148)

     – Otherwise, when PredFlagLY[ $xNbA_k$ ][ $yNbA_k$ ] (with Y = !X) is equal to 1 and LongTermRefPic( currPic, currPb, refIdxLX, RefPicListX ) is equal to LongTermRefPic( currPic, currPb, RefIdxLY[ $xNbA_k$ ][ $yNbA_k$ ], RefPicListY ), availableFlagLXA is set equal to 1 and the following assignments are made:

       mvLXA = MvLY[ $xNbA_k$ ][ $yNbA_k$ ] (8-149)

       refIdxA = RefIdxLY[ $xNbA_k$ ][ $yNbA_k$ ] (8-150)

       refPicListA = RefPicListY (8-151)

   – When availableFlagLXA is equal to 1, DiffPicOrderCnt( refPicListA[ refIdxA ], RefPicListX[ refIdxLX ] ) is not equal to 0, and both refPicListA[ refIdxA ] and RefPicListX[ refIdxLX ] are short-term reference pictures, mvLXA is derived as follows:

     tx = ( 16384 + ( Abs( td ) >> 1 ) ) / td (8-152)

     distScaleFactor = Clip3( −4096, 4095, ( tb * tx + 32 ) >> 6 ) (8-153)

     mvLXA = Clip3( −32768, 32767, Sign( distScaleFactor * mvLXA ) *
     ( ( Abs( distScaleFactor * mvLXA ) + 127 ) >> 8 ) ) (8-154)

   where td and tb are derived as follows:

     td = Clip3( −128, 127, DiffPicOrderCnt( currPic, refPicListA[ refIdxA ] ) ) (8-155)

     tb = Clip3( −128, 127, DiffPicOrderCnt( currPic, RefPicListX[ refIdxLX ] ) ) (8-156)

The motion vector mvLXB and the availability flag availableFlagLXB are derived in the following ordered steps:

1. The sample locations ( $xNbB_0$, $yNbB_0$ ), ( $xNbB_1$, $yNbB_1$ ), and ( $xNbB_2$, $yNbB_2$ ) are set equal to ( xPb + nPbW, yPb − 1 ), ( xPb + nPbW − 1, yPb − 1 ), and ( xPb − 1, yPb − 1 ), respectively.

2. The availability flag availableFlagLXB is set equal to 0 and the both components of mvLXB are set equal to 0.

3. The following applies for ( $xNbB_k$, $yNbB_k$ ) from ( $xNbB_0$, $yNbB_0$ ) to ( $xNbB_2$, $yNbB_2$ ):

   – The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma prediction block location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNbY, yNbY ) set equal to ( $xNbB_k$, $yNbB_k$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableB_k$.

   – When $availableB_k$ is equal to TRUE and availableFlagLXB is equal to 0, the following applies:

     – If PredFlagLX[ $xNbB_k$ ][ $yNbB_k$ ] is equal to 1, and DiffPicOrderCnt( RefPicListX[ RefIdxLX[ $xNbB_k$ ][ $yNbB_k$ ] ], RefPicListX[ refIdxLX ] ) is equal to 0, availableFlagLXB is set equal to 1 and the following assignments are made:

$$mvLXB = MvLX[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-157}$$

$$refIdxB = RefIdxLX[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-158}$$

     – Otherwise, when PredFlagLY[ $xNbB_k$ ][ $yNbB_k$ ] (with Y = !X) is equal to 1 and DiffPicOrderCnt( RefPicListY[ RefIdxLY[ $xNbB_k$ ][ $yNbB_k$ ] ], RefPicListX[ refIdxLX ] ) is equal to 0, availableFlagLXB is set equal to 1 and the following assignments are made:

$$mvLXB = MvLY[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-159}$$

$$refIdxB = RefIdxLY[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-160}$$

4. When isScaledFlagLX is equal to 0 and availableFlagLXB is equal to 1, availableFlagLXA is set equal to 1 and the following applies:

$$mvLXA = mvLXB \tag{8-161}$$

5. When isScaledFlagLX is equal to 0, availableFlagLXB is set equal to 0 and the following applies for ( $xNbB_k$, $yNbB_k$ ) from ( $xNbB_0$, $yNbB_0$ ) to ( $xNbB_2$, $yNbB_2$ ) or until availableFlagLXB is equal to 1:

   – The availability derivation process for a prediction block as specified in subclause 6.4.2 is invoked with the luma location ( xCb, yCb ), the current luma coding block size nCbS, the luma location ( xPb, yPb ), the luma prediction block width nPbW, the luma prediction block height nPbH, the luma location ( xNbY, yNbY ) set equal to ( $xNbB_k$, $yNbB_k$ ), and the partition index partIdx as inputs, and the output is assigned to the prediction block availability flag $availableB_k$.

   – When $availableB_k$ is equal to TRUE and availableFlagLXB is equal to 0, the following applies:

     – If PredFlagLX[ $xNbB_k$ ][ $yNbB_k$ ] is equal to 1 and LongTermRefPic( currPic, currPb, refIdxLX, RefPicListX ) is equal to LongTermRefPic( currPic, currPb, RefIdxLX[ $xNbB_k$ ][ $yNbB_k$ ], RefPicListX ), availableFlagLXB is set equal to 1 and the following assignments are made:

$$mvLXB = MvLX[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-162}$$

$$refIdxB = RefIdxLX[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-163}$$

$$refPicListB = RefPicListX \tag{8-164}$$

     – Otherwise, when PredFlagLY[ $xNbB_k$ ][ $yNbB_k$ ] (with Y = !X) is equal to 1 and LongTermRefPic( currPic, currPb, refIdxLX, RefPicListX ) is equal to LongTermRefPic( currPic, currPb, RefIdxLY[ $xNbB_k$ ][ $yNbB_k$ ], RefPicListY ), availableFlagLXB is set equal to 1 and the following assignments are made:

$$mvLXB = MvLY[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-165}$$

$$refIdxB = RefIdxLY[\ xNbB_k\ ][\ yNbB_k\ ] \tag{8-166}$$

$$refPicListB = RefPicListY \tag{8-167}$$

   – When availableFlagLXB is equal to 1, DiffPicOrderCnt( refPicListB[ refIdxB ], RefPicListX[ refIdxLX ] ) is not equal to 0, and both refPicListB[ refIdxB ] and RefPicListX[ refIdxLX ] are short-term reference pictures, mvLXB is derived as follows;

$$tx = (\ 16384 + (\ Abs(\ td\ ) >> 1\ )\ ) / td \tag{8-168}$$

$$distScaleFactor = Clip3(\ -4096, 4095, (\ tb * tx + 32\ ) >> 6\ ) \tag{8-169}$$

$$mvLXB = Clip3( -32768, 32767, Sign( distScaleFactor * mvLXB ) * ( ( Abs( distScaleFactor * mvLXB ) + 127 ) >> 8 ) ) \quad (8-170)$$

where td and tb are derived as follows:

$$td = Clip3( -128, 127, DiffPicOrderCnt( currPic, refPicListB[ refIdxB ] ) ) \quad (8-171)$$

$$tb = Clip3( -128, 127, DiffPicOrderCnt( currPic, RefPicListX[ refIdxLX ] ) ) \quad (8-172)$$

#### 8.5.3.2.7 Derivation process for temporal luma motion vector prediction

Inputs to this process are:

– a luma location ( xPb, yPb ) specifying the top-left sample of the current luma prediction block relative to the top-left luma sample of the current picture,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– a reference index refIdxLX, with X being 0 or 1.

Outputs of this process are:

– the motion vector prediction mvLXCol,

– the availability flag availableFlagLXCol.

The variable currPb specifies the current luma prediction block at luma location ( xPb, yPb ).

The variables mvLXCol and availableFlagLXCol are derived as follows:

– If slice_temporal_mvp_enabled_flag is equal to 0, both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.

– Otherwise, the following ordered steps apply:

1. Depending on the values of slice_type, collocated_from_l0_flag, and collocated_ref_idx, the variable colPic, specifying the collocated picture, is derived as follows:

   – If slice_type is equal to B and collocated_from_l0_flag is equal to 0, colPic is set equal to RefPicList1[ collocated_ref_idx ].

   – Otherwise (slice_type is equal to B and collocated_from_l0_flag is equal to 1 or slice_type is equal to P), colPic is set equal to RefPicList0[ collocated_ref_idx ].

2. The bottom right collocated motion vector is derived as follows:

$$xColBr = xPb + nPbW \quad (8-173)$$

$$yColBr = yPb + nPbH \quad (8-174)$$

   – If yPb >> CtbLog2SizeY is equal to yColBr >> CtbLog2SizeY, yColBr is less than pic_height_in_luma_samples, and xColBr is less than pic_width_in_luma_samples, the following applies:

     – The variable colPb specifies the luma prediction block covering the modified location given by ( ( xColBr >> 4 ) << 4, ( yColBr >> 4 ) << 4 ) inside the collocated picture specified by colPic.

     – The luma location ( xColPb, yColPb ) is set equal to the top-left sample of the collocated luma prediction block specified by colPb relative to the top-left luma sample of the collocated picture specified by colPic.

     – The derivation process for collocated motion vectors as specified in subclause 8.5.3.2.8 is invoked with currPb, colPic, colPb, ( xColPb, yColPb ), and refIdxLX as inputs, and the output is assigned to mvLXCol and availableFlagLXCol.

   – Otherwise, both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.

3. When availableFlagLXCol is equal to 0, the central collocated motion vector is derived as follows:

$$xColCtr = xPb + ( nPbW >> 1 ) \quad (8-175)$$

$$yColCtr = yPb + ( nPbH >> 1 ) \quad (8-176)$$

   – The variable colPb specifies the luma prediction block covering the modified location given by ( ( xColCtr >> 4 ) << 4, ( yColCtr >> 4 ) << 4 ) inside the colPic.

  - The luma location ( xColPb, yColPb ) is set equal to the top-left sample of the collocated luma prediction block specified by colPb relative to the top-left luma sample of the collocated picture specified by colPic.
  - The derivation process for collocated motion vectors as specified in subclause 8.5.3.2.8 is invoked with currPb, colPic, colPb, ( xColPb, yColPb ), and refIdxLX as inputs, and the output is assigned to mvLXCol and availableFlagLXCol.

#### 8.5.3.2.8 Derivation process for collocated motion vectors

Inputs to this process are:

- a variable currPb specifying the current prediction block,
- a variable colPic specifying the collocated picture,
- a variable colPb specifying the collocated prediction block inside the collocated picture specified by colPic,
- a luma location ( xColPb, yColPb ) specifying the top-left sample of the collocated luma prediction block specified by colPb relative to the top-left luma sample of the collocated picture specified by colPic,
- a reference index refIdxLX, with X being 0 or 1.

Outputs of this process are:

- the motion vector prediction mvLXCol,
- the availability flag availableFlagLXCol.

The variable currPic specifies the current picture.

The arrays predFlagLXCol[ x ][ y ], mvLXCol[ x ][ y ], and refIdxLXCol[ x ][ y ] are set equal to the corresponding arrays of the collocated picture specified by colPic, PredFlagLX[ x ][ y ], MvLX[ x ][ y ], and RefIdxLX[ x ][ y ], respectively, with X being the value of X this process is invoked for.

The variables mvLXCol and availableFlagLXCol are derived as follows:

- If colPb is coded in an intra prediction mode, both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.
- Otherwise, the motion vector mvCol, the reference index refIdxCol, and the reference list identifier listCol are derived as follows:
  - If predFlagL0Col[ xColPb ][ yColPb ] is equal to 0, mvCol, refIdxCol, and listCol are set equal to mvL1Col[ xColPb ][ yColPb ], refIdxL1Col[ xColPb ][ yColPb ], and L1, respectively.
  - Otherwise, if predFlagL0Col[ xColPb ][ yColPb ] is equal to 1 and predFlagL1Col[ xColPb ][ yColPb ] is equal to 0, mvCol, refIdxCol, and listCol are set equal to mvL0Col[ xColPb ][ yColPb ], refIdxL0Col[ xColPb ][ yColPb ], and L0, respectively.
  - Otherwise (predFlagL0Col[ xColPb ][ yColPb ] is equal to 1 and predFlagL1Col[ xColPb ][ yColPb ] is equal to 1), the following assignments are made:
    - If DiffPicOrderCnt( aPic, currPic ) is less than or equal to 0 for every picture aPic in every reference picture list of the current slice, mvCol, refIdxCol, and listCol are set equal to mvLXCol[ xColPb ][ yColPb ], refIdxLXCol[ xColPb ][ yColPb ] and LX, respectively.
    - Otherwise, mvCol, refIdxCol, and listCol are set equal to mvLNCol[ xColPb ][ yColPb ], refIdxLNCol[ xColPb ][ yColPb ], and LN, respectively, with N being the value of collocated_from_l0_flag.

  and mvLXCol and availableFlagLXCol are derived as follows:
  - If LongTermRefPic( currPic, currPb, refIdxLX, LX ) is not equal to LongTermRefPic( colPic, colPb, refIdxCol, listCol ), both components of mvLXCol are set equal to 0 and availableFlagLXCol is set equal to 0.
  - Otherwise, the variable availableFlagLXCol is set equal to 1, refPicListCol[ refIdxCol ] is set to be the picture with reference index refIdxCol in the reference picture list listCol of the slice containing prediction block currPb in the picture colPic, and the following applies:

$$\text{colPocDiff} = \text{DiffPicOrderCnt}(\text{ colPic, refPicListCol[ refIdxCol ] })\quad (8\text{-}177)$$

$$\text{currPocDiff} = \text{DiffPicOrderCnt}(\text{ currPic, RefPicListX[ refIdxLX ] })\quad (8\text{-}178)$$

– If RefPicListX[ refIdxLX ] is a long-term reference picture, or colPocDiff is equal to currPocDiff, mvLXCol is derived as follows:

$$\text{mvLXCol} = \text{mvCol} \tag{8-179}$$

– Otherwise, mvLXCol is derived as a scaled version of the motion vector mvCol as follows:

$$\text{tx} = ( 16384 + ( \text{Abs}( \text{td} ) >> 1 ) ) / \text{td} \tag{8-180}$$

$$\text{distScaleFactor} = \text{Clip3}( -4096, 4095, ( \text{tb} * \text{tx} + 32 ) >> 6 ) \tag{8-181}$$

$$\text{mvLXCol} = \text{Clip3}( -32768, 32767, \text{Sign}( \text{distScaleFactor} * \text{mvCol} ) * ( ( \text{Abs}( \text{distScaleFactor} * \text{mvCol} ) + 127 ) >> 8 ) ) \tag{8-182}$$

where td and tb are derived as follows:

$$\text{td} = \text{Clip3}( -128, 127, \text{colPocDiff} ) \tag{8-183}$$

$$\text{tb} = \text{Clip3}( -128, 127, \text{currPocDiff} ) \tag{8-184}$$

#### 8.5.3.2.9 Derivation process for chroma motion vectors

Input to this process is a luma motion vector mvLX.

Output of this process is a chroma motion vector mvCLX.

A chroma motion vector is derived from the corresponding luma motion vector.

For the derivation of the chroma motion vector mvCLX, the following applies:

$$\text{mvCLX}[ 0 ] = \text{mvLX}[ 0 ] \tag{8-185}$$

$$\text{mvCLX}[ 1 ] = \text{mvLX}[ 1 ] \tag{8-186}$$

### 8.5.3.3 Decoding process for inter prediction samples

#### 8.5.3.3.1 General

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) specifying the top-left sample of the current luma prediction block relative to the top-left sample of the current luma coding block,

– a variable nCbS specifying the size of the current luma coding block,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– the luma motion vectors mvL0 and mvL1,

– the chroma motion vectors mvCL0 and mvCL1,

– the reference indices refIdxL0 and refIdxL1,

– the prediction list utilization flags, predFlagL0, and predFlagL1.

Outputs of this process are:

– an $(\text{nCbS}_L)\text{x}(\text{nCbS}_L)$ array $\text{predSamples}_L$ of luma prediction samples, where $\text{nCbS}_L$ is derived as specified below,

– an $(\text{nCbS}_C)\text{x}(\text{nCbS}_C)$ array $\text{preSamples}_{Cb}$ of chroma prediction samples for the component Cb, where $\text{nCbS}_C$ is derived as specified below,

– an $(\text{nCbS}_C)\text{x}(\text{nCbS}_C)$ array $\text{predSamples}_{Cr}$ of chroma residual samples for the component Cr, where $\text{nCbS}_C$ is derived as specified below.

The variable $\text{nCbS}_L$ is set equal to nCbS and the variable $\text{nCbS}_C$ is set equal to nCbS >> 1.

Let $\text{predSamplesL0}_L$ and $\text{predSamplesL1}_L$ be (nPbW)x(nPbH) arrays of predicted luma sample values and $\text{predSampleL0}_{Cb}$, $\text{predSampleL1}_{Cb}$, $\text{predSampleL0}_{Cr}$, and $\text{predSampleL1}_{Cr}$ be (nPbW / 2)x(nPbH / 2) arrays of predicted chroma sample values.

For X being each of 0 and 1, when predFlagLX is equal to 1, the following applies:

– The reference picture consisting of an ordered two-dimensional array $refPicLX_L$ of luma samples and two ordered two-dimensional arrays $refPicLX_{Cb}$ and $refPicLX_{Cr}$ of chroma samples is derived by invoking the process specified in subclause 8.5.3.3.2 with refIdxLX as input.

– The arrays $predSamplesLX_L$, $predSamplesLX_{Cb}$, and $predSamplesLX_{Cr}$ are derived by invoking the fractional sample interpolation process specified in subclause 8.5.3.3.3 with the luma locations ( xCb, yCb ) and ( xBl, yBl ), the luma prediction block width nPbW, the luma prediction block height nPbH, the motion vectors mvLX and mvCLX, and the reference arrays $refPicLX_L$, $refPicLX_{Cb}$, and $refPicLX_{Cr}$ as inputs.

The array $predSample_L$ of the prediction samples of luma component is derived by invoking the weighted sample prediction process specified in subclause 8.5.3.3.4 with the luma prediction block width nPbW, the luma prediction block height nPbH, and the sample arrays $predSamplesL0_L$ and $predSamplesL1_L$, and the variables predFlagL0, predFlagL1, refIdxL0, refIdxL1, and cIdx equal to 0 as inputs.

The array $predSample_{Cb}$ of the prediction samples of component Cb is derived by invoking the weighted sample prediction process specified in subclause 8.5.3.3.4 with the chroma prediction block width $nPbW_{Cb}$ set equal to nPbW / 2, the chroma prediction block height $nPbH_{Cb}$ set equal to nPbH / 2, the sample arrays $predSamplesL0_{Cb}$ and $predSamplesL1_{Cb}$, and the variables predFlagL0, predFlagL1, refIdxL0, refIdxL1, and cIdx equal to 1 as inputs.

The array $predSample_{Cr}$ of the prediction samples of component Cr is derived by invoking the weighted sample prediction process specified in subclause 8.5.3.3.4 with the chroma prediction block width $nPbW_{Cr}$ set equal to nPbW / 2, the chroma prediction block height $nPbH_{Cr}$ set equal to nPbH / 2, the sample arrays $predSamplesL0_{Cr}$ and $predSamplesL1_{Cr}$, and the variables predFlagL0, predFlagL1, refIdxL0, refIdxL1, and cIdx equal to 2 as inputs.

### 8.5.3.3.2 Reference picture selection process

Input to this process is a reference index refIdxLX.

Output of this process is a reference picture consisting of a two-dimensional array of luma samples $refPicLX_L$ and two two-dimensional arrays of chroma samples $refPicLX_{Cb}$ and $refPicLX_{Cr}$.

The output reference picture RefPicListX[ refIdxLX ] consists of a pic_width_in_luma_samples by pic_height_in_luma_samples array of luma samples $refPicLX_L$ and two PicWidthInSamplesC by PicHeightInSamplesC arrays of chroma samples $refPicLX_{Cb}$ and $refPicLX_{Cr}$.

The reference picture sample arrays $refPicLX_L$, $refPicLX_{Cb}$, and $refPicLX_{Cr}$ correspond to decoded sample arrays $S_L$, $S_{Cb}$, and $S_{Cr}$ derived in subclause 8.7 for a previously-decoded picture.

### 8.5.3.3.3 Fractional sample interpolation process

#### 8.5.3.3.3.1 General

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) specifying the top-left sample of the current luma prediction block relative to the top-left sample of the current luma coding block,

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– a luma motion vector mvLX given in quarter-luma-sample units,

– a chroma motion vector mvCLX given in eighth-chroma-sample units,

– the selected reference picture sample arrays $refPicLX_L$, $refPicLX_{Cb}$, and $refPicLX_{Cr}$.

Outputs of this process are:

– an (nPbW)x(nPbH) array $predSampleLX_L$ of prediction luma sample values,

– two (nPbW / 2)x(nPbH / 2) arrays $predSampleLX_{Cb}$, and $predSampleLX_{Cr}$ of prediction chroma sample values.

The location ( xPb, yPb ) given in full-sample units of the upper-left luma samples of the current prediction block relative to the upper-left luma sample location of the given reference sample arrays is derived as follows:

$$xPb = xCb + xBl \quad (8\text{-}187)$$

$$yPb = yCb + yBl \quad (8\text{-}188)$$

Let ( $xInt_L$, $yInt_L$ ) be a luma location given in full-sample units and ( $xFrac_L$, $yFrac_L$ ) be an offset given in quarter-sample units. These variables are used only inside this subclause for specifying fractional-sample locations inside the reference sample arrays $refPicLX_L$, $refPicLX_{Cb}$, and $refPicLX_{Cr}$.

For each luma sample location ( $x_L = 0..nPbW - 1$, $y_L = 0..nPbH - 1$ ) inside the prediction luma sample array $predSampleLX_L$, the corresponding prediction luma sample value $predSampleLX_L[ x_L, y_L ]$ is derived as follows:

– The variables $xInt_L$, $yInt_L$, $xFrac_L$, and $yFrac_L$ are derived as follows:

$$xInt_L = xPb + ( mvLX[ 0 ] >> 2 ) + x_L \tag{8-189}$$

$$yInt_L = yPb + ( mvLX[ 1 ] >> 2 ) + y_L \tag{8-190}$$

$$xFrac_L = mvLX[ 0 ] \mathbin{\&} 3 \tag{8-191}$$

$$yFrac_L = mvLX[ 1 ] \mathbin{\&} 3 \tag{8-192}$$

– The prediction luma sample value $predSampleLX_L[ x_L, y_L ]$ is derived by invoking the process specified in subclause 8.5.3.3.3.2 with ( $xInt_L$, $yInt_L$ ), ( $xFrac_L$, $yFrac_L$ ), and $refPicLX_L$ as inputs.

Let ( $xInt_C$, $yInt_C$ ) be a chroma location given in full-sample units and ( $xFrac_C$, $yFrac_C$ ) be an offset given in one-eighth sample units. These variables are used only inside this subclause for specifying general fractional-sample locations inside the reference sample arrays $refPicLX_{Cb}$ and $refPicLX_{Cr}$.

For each chroma sample location ( $x_C = 0..nPbW / 2 - 1$, $y_C = 0..nPbH / 2 - 1$ ) inside the prediction chroma sample arrays $predSampleLX_{Cb}$ and $predSampleLX_{Cr}$, the corresponding prediction chroma sample values $predSampleLX_{Cb}[ x_C, y_C ]$ and $predSampleLX_{Cr}[ x_C, y_C ]$ are derived as follows:

– The variables $xInt_C$, $yInt_C$, $xFrac_C$, and $yFrac_C$ are derived as follows:

$$xInt_C = ( xPb / 2 ) + ( mvCLX[ 0 ] >> 3 ) + x_C \tag{8-193}$$

$$yInt_C = ( yPb / 2 ) + ( mvCLX[ 1 ] >> 3 ) + y_C \tag{8-194}$$

$$xFrac_C = mvLX[ 0 ] \mathbin{\&} 7 \tag{8-195}$$

$$yFrac_C = mvLX[ 1 ] \mathbin{\&} 7 \tag{8-196}$$

– The prediction sample value $predSampleLX_{Cb}[ x_C, y_C ]$ is derived by invoking the process specified in subclause 8.5.3.3.3.3 with ( $xInt_C$, $yInt_C$ ), ( $xFrac_C$, $yFrac_C$ ), and $refPicLX_{Cb}$ as inputs.

– The prediction sample value $predSampleLX_{Cr}[ x_C, y_C ]$ is derived by invoking the process specified in subclause 8.5.3.3.3.3 with ( $xInt_C$, $yInt_C$ ), ( $xFrac_C$, $yFrac_C$ ), and $refPicLX_{Cr}$ as inputs.

#### 8.5.3.3.3.2 Luma sample interpolation process

Inputs to this process are:

– a luma location in full-sample units ( $xInt_L$, $yInt_L$ ),

– a luma location in fractional-sample units ( $xFrac_L$, $yFrac_L$ ),

– the luma reference sample array $refPicLX_L$.

Output of this process is a predicted luma sample value $predSampleLX_L[ x_L, y_L ]$

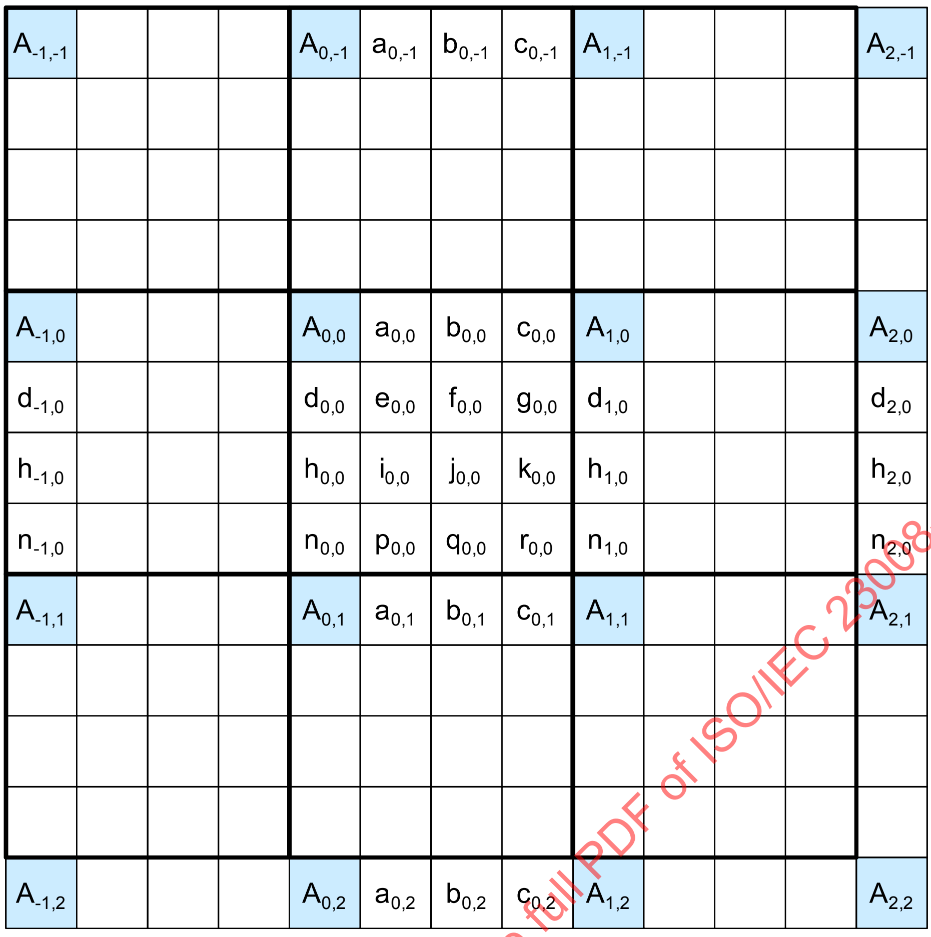

$A_{-1,-1}$ $A_{0,-1}$ $a_{0,-1}$ $b_{0,-1}$ $c_{0,-1}$ $A_{1,-1}$ $A_{2,-1}$
$A_{-1,0}$ $A_{0,0}$ $a_{0,0}$ $b_{0,0}$ $c_{0,0}$ $A_{1,0}$ $A_{2,0}$
$d_{-1,0}$ $d_{0,0}$ $e_{0,0}$ $f_{0,0}$ $g_{0,0}$ $d_{1,0}$ $d_{2,0}$
$h_{-1,0}$ $h_{0,0}$ $i_{0,0}$ $j_{0,0}$ $k_{0,0}$ $h_{1,0}$ $h_{2,0}$
$n_{-1,0}$ $n_{0,0}$ $p_{0,0}$ $q_{0,0}$ $r_{0,0}$ $n_{1,0}$ $n_{2,0}$
$A_{-1,1}$ $A_{0,1}$ $a_{0,1}$ $b_{0,1}$ $c_{0,1}$ $A_{1,1}$ $A_{2,1}$
$A_{-1,2}$ $A_{0,2}$ $a_{0,2}$ $b_{0,2}$ $c_{0,2}$ $A_{1,2}$ $A_{2,2}$

**Figure 8-4 – Integer samples (shaded blocks with upper-case letters) and fractional sample positions (un-shaded blocks with lower-case letters) for quarter sample luma interpolation**

In Figure 8-4, the positions labelled with upper-case letters $A_{i,j}$ within shaded blocks represent luma samples at full-sample locations inside the given two-dimensional array $refPicLX_L$ of luma samples. These samples may be used for generating the predicted luma sample value $predSampleLX_L[ x_L, y_L ]$. The locations $( xA_{i,j}, yA_{i,j} )$ for each of the corresponding luma samples $A_{i,j}$ inside the given array $refPicLX_L$ of luma samples are derived as follows:

$$xA_{i,j} = Clip3( 0, pic\_width\_in\_luma\_samples - 1, xInt_L + i ) \quad (8\text{-}197)$$

$$yA_{i,j} = Clip3( 0, pic\_height\_in\_luma\_samples - 1, yInt_L + j ) \quad (8\text{-}198)$$

The positions labelled with lower-case letters within un-shaded blocks represent luma samples at quarter-pel sample fractional locations. The luma location offset in fractional-sample units $( xFrac_L, yFrac_L )$ specifies which of the generated luma samples at full-sample and fractional-sample locations is assigned to the predicted luma sample value $predSampleLX_L[ x_L, y_L ]$. This assignment is as specified in Table 8-7. The value of $predSampleLX_L[ x_L, y_L ]$ is the output.

The variables shift1, shift2, and shift3 are derived as follows:

– The variable shift1 is set equal to $BitDepth_Y - 8$, the variable shift2 is set equal to 6, and the variable shift3 is set equal to $14 - BitDepth_Y$.

Given the luma samples $A_{i,j}$ at full-sample locations $( xA_{i,j}, yA_{i,j} )$, the luma samples $a_{0,0}$ to $r_{0,0}$ at fractional sample positions are derived as follows:

– The samples labelled $a_{0,0}$, $b_{0,0}$, $c_{0,0}$, $d_{0,0}$, $h_{0,0}$, and $n_{0,0}$ are derived by applying an 8-tap filter to the nearest integer position samples as follows:

$$a_{0,0} = ( -A_{-3,0} + 4 * A_{-2,0} - 10 * A_{-1,0} + 58 * A_{0,0} + 17 * A_{1,0} - 5 * A_{2,0} + A_{3,0} ) >> shift1 \quad (8\text{-}199)$$

$$b_{0,0} = ( -A_{-3,0} + 4 * A_{-2,0} - 11 * A_{-1,0} + 40 * A_{0,0} + 40 * A_{1,0} - 11 * A_{2,0} + 4 * A_{3,0} - A_{4,0} ) >> shift1 \quad (8\text{-}200)$$

$$c_{0,0} = ( A_{-2,0} - 5 * A_{-1,0} + 17 * A_{0,0} + 58 * A_{1,0} - 10 * A_{2,0} + 4 * A_{3,0} - A_{4,0} ) >> shift1 \quad (8\text{-}201)$$

$d_{0,0} = ( -A_{0,-3} + 4 * A_{0,-2} - 10 * A_{0,-1} + 58 * A_{0,0} + 17 * A_{0,1} - 5 * A_{0,2} + A_{0,3} ) >> \text{shift1}$ (8-202)

$h_{0,0} = ( -A_{0,-3} + 4 * A_{0,-2} - 11 * A_{0,-1} + 40 * A_{0,0} + 40 * A_{0,1} - 11 * A_{0,2} + 4 * A_{0,3} - A_{0,4} ) >> \text{shift1}$ (8-203)

$n_{0,0} = ( A_{0,-2} - 5 * A_{0,-1} + 17 * A_{0,0} + 58 * A_{0,1} - 10 * A_{0,2} + 4 * A_{0,3} - A_{0,4} ) >> \text{shift1}$ (8-204)

– The samples labelled $e_{0,0}$, $i_{0,0}$, $p_{0,0}$, $f_{0,0}$, $j_{0,0}$, $q_{0,0}$, $g_{0,0}$, $k_{0,0}$, and $r_{0,0}$ are derived by applying an 8-tap filter to the samples $a_{0,i}$, $b_{0,i}$ and $c_{0,i}$ with $i = -3..4$ in the vertical direction as follows:

$e_{0,0} = ( -a_{0,-3} + 4 * a_{0,-2} - 10 * a_{0,-1} + 58 * a_{0,0} + 17 * a_{0,1} - 5 * a_{0,2} + a_{0,3} ) >> \text{shift2}$ (8-205)

$i_{0,0} = ( -a_{0,-3} + 4 * a_{0,-2} - 11 * a_{0,-1} + 40 * a_{0,0} + 40 * a_{0,1} - 11 * a_{0,2} + 4 * a_{0,3} - a_{0,4} ) >> \text{shift2}$ (8-206)

$p_{0,0} = ( a_{0,-2} - 5 * a_{0,-1} + 17 * a_{0,0} + 58 * a_{0,1} - 10 * a_{0,2} + 4 * a_{0,3} - a_{0,4} ) >> \text{shift2}$ (8-207)

$f_{0,0} = ( -b_{0,-3} + 4 * b_{0,-2} - 10 * b_{0,-1} + 58 * b_{0,0} + 17 * b_{0,1} - 5 * b_{0,2} + b_{0,3} ) >> \text{shift2}$ (8-208)

$j_{0,0} = ( -b_{0,-3} + 4 * b_{0,-2} - 11 * b_{0,-1} + 40 * b_{0,0} + 40 * b_{0,1} - 11 * b_{0,2} + 4 * b_{0,3} - b_{0,4} ) >> \text{shift2}$ (8-209)

$q_{0,0} = ( b_{0,-2} - 5 * b_{0,-1} + 17 * b_{0,0} + 58 * b_{0,1} - 10 * b_{0,2} + 4 * b_{0,3} - b_{0,4} ) >> \text{shift2}$ (8-210)

$g_{0,0} = ( -c_{0,-3} + 4 * c_{0,-2} - 10 * c_{0,-1} + 58 * c_{0,0} + 17 * c_{0,1} - 5 * c_{0,2} + c_{0,3} ) >> \text{shift2}$ (8-211)

$k_{0,0} = ( -c_{0,-3} + 4 * c_{0,-2} - 11 * c_{0,-1} + 40 * c_{0,0} + 40 * c_{0,1} - 11 * c_{0,2} + 4 * c_{0,3} - c_{0,4} ) >> \text{shift2}$ (8-212)

$r_{0,0} = ( c_{0,-2} - 5 * c_{0,-1} + 17 * c_{0,0} + 58 * c_{0,1} - 10 * c_{0,2} + 4 * c_{0,3} - c_{0,4} ) >> \text{shift2}$ (8-213)

**Table 8-7 – Assignment of the luma prediction sample predSampleLX$_L$[ x$_L$, y$_L$ ]**

| **xFracL** | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **yFracL** | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 | 0 | 1 | 2 | 3 |
| **predSampleLX$_L$[ x$_L$, y$_L$ ]** | A << shift3 | d | h | n | a | e | i | p | b | f | j | q | c | g | k | r |

## 8.5.3.3.3.3 Chroma sample interpolation process

Inputs to this process are:

– a chroma location in full-sample units ( xInt$_C$, yInt$_C$ ),

– a chroma location in fractional-sample units ( xFrac$_C$, yFrac$_C$ ),

– the chroma reference sample array refPicLX$_C$.

Output of this process is a predicted chroma sample value predSampleLX$_C$[ x$_C$, y$_C$ ]

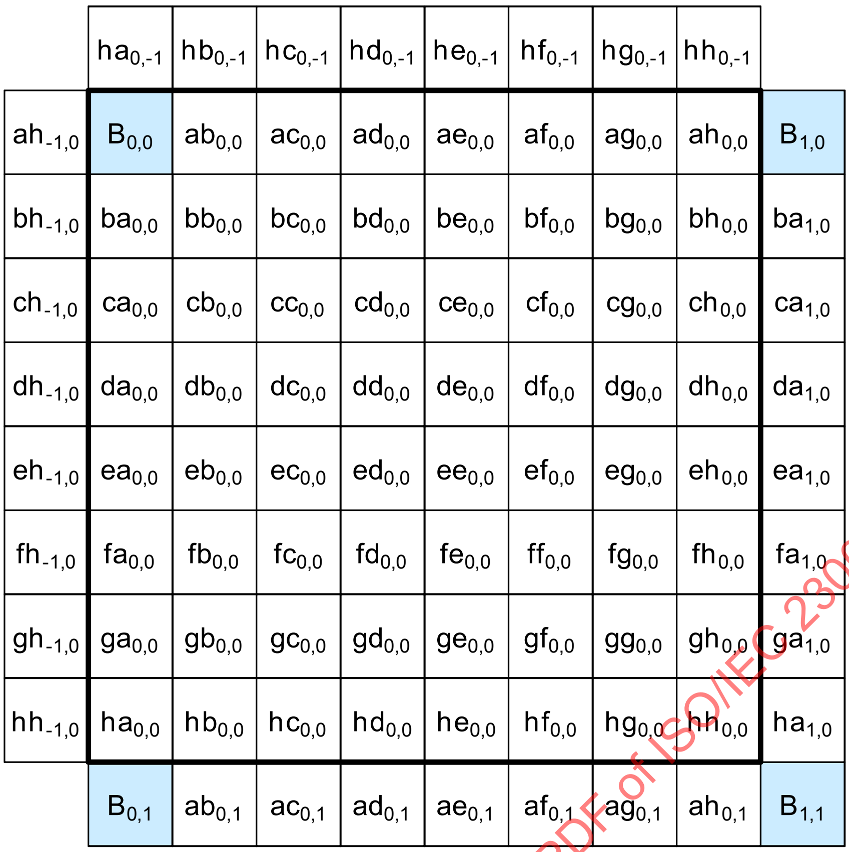

ha0,-1 hb0,-1 hc0,-1 hd0,-1 he0,-1 hf0,-1 hg0,-1 hh0,-1
ah-1,0 B0,0 ab0,0 ac0,0 ad0,0 ae0,0 af0,0 ag0,0 ah0,0 B1,0
bh-1,0 ba0,0 bb0,0 bc0,0 bd0,0 be0,0 bf0,0 bg0,0 bh0,0 ba1,0
ch-1,0 ca0,0 cb0,0 cc0,0 cd0,0 ce0,0 cf0,0 cg0,0 ch0,0 ca1,0
dh-1,0 da0,0 db0,0 dc0,0 dd0,0 de0,0 df0,0 dg0,0 dh0,0 da1,0
eh-1,0 ea0,0 eb0,0 ec0,0 ed0,0 ee0,0 ef0,0 eg0,0 eh0,0 ea1,0
fh-1,0 fa0,0 fb0,0 fc0,0 fd0,0 fe0,0 ff0,0 fg0,0 fh0,0 fa1,0
gh-1,0 ga0,0 gb0,0 gc0,0 gd0,0 ge0,0 gf0,0 gg0,0 gh0,0 ga1,0
hh-1,0 ha0,0 hb0,0 hc0,0 hd0,0 he0,0 hf0,0 hg0,0 hh0,0 ha1,0
B0,1 ab0,1 ac0,1 ad0,1 ae0,1 af0,1 ag0,1 ah0,1 B1,1

**Figure 8-5 – Integer samples (shaded blocks with upper-case letters) and fractional sample positions (un-shaded blocks with lower-case letters) for eighth sample chroma interpolation**

In Figure 8-5, the positions labelled with upper-case letters $B_{i,j}$ within shaded blocks represent chroma samples at full-sample locations inside the given two-dimensional array $refPicLX_C$ of chroma samples. These samples may be used for generating the predicted chroma sample value $predSampleLX_C[\ x_C, y_C\ ]$. The locations $(\ xB_{i,j}, yB_{i,j}\ )$ for each of the corresponding chroma samples $B_{i,j}$ inside the given array $refPicLX_C$ of chroma samples are derived as follows:

$$xB_{i,j} = \text{Clip3}(\ 0, (\ \text{pic\_width\_in\_luma\_samples} / \text{SubWidthC}\ ) - 1, xInt_C + i\ ) \quad (8\text{-}214)$$

$$yB_{i,j} = \text{Clip3}(\ 0, (\ \text{pic\_height\_in\_luma\_samples} / \text{SubHeightC}\ ) - 1, yInt_C + j\ ) \quad (8\text{-}215)$$

The positions labelled with lower-case letters within un-shaded blocks represent chroma samples at eighth-pel sample fractional locations. The chroma location offset in fractional-sample units $(\ xFrac_C, yFrac_C\ )$ specifies which of the generated chroma samples at full-sample and fractional-sample locations is assigned to the predicted chroma sample value $predSampleLX_C[\ x_C, y_C\ ]$. This assignment is as specified in Table 8-8. The output is the value of $predSampleLX_C[\ x_C, y_C\ ]$.

The variables shift1, shift2, and shift3 are derived as follows:

– The variable shift1 is set equal to $BitDepth_C - 8$, the variable shift2 is set equal to 6, and the variable shift3 is set equal to $14 - BitDepth_C$.

Given the chroma samples $B_{i,j}$ at full-sample locations $(\ xB_{i,j}, yB_{i,j}\ )$, the chroma samples $ab_{0,0}$ to $hh_{0,0}$ at fractional sample positions are derived as follows:

– The samples labelled $ab_{0,0}$, $ac_{0,0}$, $ad_{0,0}$, $ae_{0,0}$, $af_{0,0}$, $ag_{0,0}$, and $ah_{0,0}$ are derived by applying a 4-tap filter to the nearest integer position samples as follows:

$$ab_{0,0} = (\ -2 * B_{-1,0} + 58 * B_{0,0} + 10 * B_{1,0} - 2 * B_{2,0}\ ) >> \text{shift1} \quad (8\text{-}216)$$

$$ac_{0,0} = (\ -4 * B_{-1,0} + 54 * B_{0,0} + 16 * B_{1,0} - 2 * B_{2,0}\ ) >> \text{shift1} \quad (8\text{-}217)$$

$$ad_{0,0} = (\ -6 * B_{-1,0} + 46 * B_{0,0} + 28 * B_{1,0} - 4 * B_{2,0}\ ) >> \text{shift1} \quad (8\text{-}218)$$

$$ae_{0,0} = (\ -4 * B_{-1,0} + 36 * B_{0,0} + 36 * B_{1,0} - 4 * B_{2,0}\ ) >> \text{shift1} \quad (8\text{-}219)$$

$$af_{0,0} = (\ -4 * B_{-1,0} + 28 * B_{0,0} + 46 * B_{1,0} - 6 * B_{2,0}\ ) >> \text{shift1} \quad (8\text{-}220)$$

$ag_{0,0} = ( -2 * B_{-1,0} + 16 * B_{0,0} + 54 * B_{1,0} - 4 * B_{2,0} ) >> shift1$ (8-221)

$ah_{0,0} = ( -2 * B_{-1,0} + 10 * B_{0,0} + 58 * B_{1,0} - 2 * B_{2,0} ) >> shift1$ (8-222)

– The samples labelled $ba_{0,0}$, $ca_{0,0}$, $da_{0,0}$, $ea_{0,0}$, $fa_{0,0}$, $ga_{0,0}$, and $ha_{0,0}$ are derived by applying a 4-tap filter to the nearest integer position samples as follows:

$ba_{0,0} = ( -2 * B_{0,-1} + 58 * B_{0,0} + 10 * B_{0,1} - 2 * B_{0,2} ) >> shift1$ (8-223)

$ca_{0,0} = ( -4 * B_{0,-1} + 54 * B_{0,0} + 16 * B_{0,1} - 2 * B_{0,2} ) >> shift1$ (8-224)

$da_{0,0} = ( -6 * B_{0,-1} + 46 * B_{0,0} + 28 * B_{0,1} - 4 * B_{0,2} ) >> shift1$ (8-225)

$ea_{0,0} = ( -4 * B_{0,-1} + 36 * B_{0,0} + 36 * B_{0,1} - 4 * B_{0,2} ) >> shift1$ (8-226)

$fa_{0,0} = ( -4 * B_{0,-1} + 28 * B_{0,0} + 46 * B_{0,1} - 6 * B_{0,2} ) >> shift1$ (8-227)

$ga_{0,0} = ( -2 * B_{0,-1} + 16 * B_{0,0} + 54 * B_{0,1} - 4 * B_{0,2} ) >> shift1$ (8-228)

$ha_{0,0} = ( -2 * B_{0,-1} + 10 * B_{0,0} + 58 * B_{0,1} - 2 * B_{0,2} ) >> shift1$ (8-229)

– The samples labelled $bX_{0,0}$, $cX_{0,0}$, $dX_{0,0}$, $eX_{0,0}$, $fX_{0,0}$, $gX_{0,0}$, and $hX_{0,0}$ for X being replaced by b, c, d, e, f, g, and h, respectively, are derived by applying an 4-tap filter to the intermediate values $aX_{0,i}$ with $i = -1..2$ in the vertical direction as follows:

$bX_{0,0} = ( -2 * aX_{0,-1} + 58 * aX_{0,0} + 10 * aX_{0,1} - 2 * aX_{0,2} ) >> shift2$ (8-230)

$cX_{0,0} = ( -4 * aX_{0,-1} + 54 * aX_{0,0} + 16 * aX_{0,1} - 2 * aX_{0,2} ) >> shift2$ (8-231)

$dX_{0,0} = ( -6 * aX_{0,-1} + 46 * aX_{0,0} + 28 * aX_{0,1} - 4 * aX_{0,2} ) >> shift2$ (8-232)

$eX_{0,0} = ( -4 * aX_{0,-1} + 36 * aX_{0,0} + 36 * aX_{0,1} - 4 * aX_{0,2} ) >> shift2$ (8-233)

$fX_{0,0} = ( -4 * aX_{0,-1} + 28 * aX_{0,0} + 46 * aX_{0,1} - 6 * aX_{0,2} ) >> shift2$ (8-234)

$gX_{0,0} = ( -2 * aX_{0,-1} + 16 * aX_{0,0} + 54 * aX_{0,1} - 4 * aX_{0,2} ) >> shift2$ (8-235)

$hX_{0,0} = ( -2 * aX_{0,-1} + 10 * aX_{0,0} + 58 * aX_{0,1} - 2 * aX_{0,2} ) >> shift2$ (8-236)

**Table 8-8 – Assignment of the chroma prediction sample predSampleLX$_C$[ $x_C$, $y_C$ ] for ( X, Y ) being replaced by ( 1, b ), ( 2, c ), ( 3, d ), ( 4, e ), ( 5, f ), ( 6, g ), and ( 7, h ), respectively**

| **xFracC** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|---|
| **yFracC** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **predSampleLX$_C$[ $x_C$, $y_C$ ]** | B << shift3 | ba | ca | da | ea | fa | ga | ha |
| | | | | | | | | |
| **xFracC** | X | X | X | X | X | X | X | X |
| **yFracC** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| **predSampleLXC[ $x_C$, $y_C$ ]** | aY | bY | cY | dY | eY | fY | gY | hY |

### 8.5.3.3.4 Weighted sample prediction process

#### 8.5.3.3.4.1 General

Inputs to this process are:

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1,

– the prediction list utilization flags, predFlagL0, and predFlagL1,

– the reference indices refIdxL0 and refIdxL1,

– a variable cIdx specifying colour component index.

Output of this process is the (nPbW)x(nPbH) array predSamples of prediction sample values.

The variable bitDepth is derived as follows:

– If cIdx is equal to 0, bitDepth is set equal to $\text{BitDepth}_Y$.

– Otherwise, bitDepth is set equal to $\text{BitDepth}_C$.

The variable weightedPredFlag is derived as follows:

– If slice_type is equal to P, weightedPredFlag is set equal to weighted_pred_flag.

– Otherwise (slice_type is equal to B), weightedPredFlag is set equal to weighted_bipred_flag.

The following applies:

– If weightedPredFlag is equal to 0, the array predSample of the prediction samples is derived by invoking the default weighted sample prediction process as specified in subclause 8.5.3.3.4.2 with the luma prediction block width nPbW, the luma prediction block height nPbH, two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1, the prediction list utilization flags predFlagL0 and predFlagL1, and the bit depth bitDepth as inputs.

– Otherwise (weightedPredFlag is equal to 1), the array predSample of the prediction samples is derived by invoking the weighted sample prediction process as specified in subclause 8.5.3.3.4.3 with the luma prediction block width nPbW, the luma prediction block height nPbH, two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1, the prediction list utilization flags predFlagL0 and predFlagL1, the reference indices refIdxL0 and refIdxL1, the colour component index cIdx, and the bit depth bitDepth as inputs.

### 8.5.3.3.4.2 Default weighted sample prediction process

Inputs to this process are:

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1,

– the prediction list utilization flags, predFlagL0, and predFlagL1,

– a bit depth of samples, bitDepth.

Output of this process is the (nPbW)x(nPbH) array predSamples of prediction sample values.

Variables shift1, shift2, offset1, and offset2 are derived as follows:

– The variable shift1 is set equal to 14 − bitDepth and the variable shift2 is set equal to 15 − bitDepth.

– The variable offset1 is derived as follows:

  – If shift1 is greater than 0, offset1 is set equal to 1 << ( shift1 − 1 ).

  – Otherwise (shift1 is equal to 0), offset1 is set equal to 0.

– The variable offset2 is set equal to 1 << ( shift2 − 1 ).

Depending on the values of predFlagL0 and predFlagL1, the prediction samples predSamples[ x ][ y ] with x = 0..nPbW − 1 and y = 0..nPbH − 1 are derived as follows:

– If predFlagL0 is equal to 1 and predFlagL1 is equal to 0, the prediction sample values are derived as follows:

$$\text{predSamples}[\,x\,][\,y\,] = \text{Clip3}(\,0,\,(\,1 \ll \text{bitDepth}\,) - 1,\,(\,\text{predSamplesL0}[\,x\,][\,y\,] + \text{offset1}\,) \gg \text{shift1}\,) \quad (8\text{-}237)$$

– Otherwise, if predFlagL0 is equal to 0 and predFlagL1 is equal to 1, the prediction sample values are derived as follows:

$$\text{predSamples}[\,x\,][\,y\,] = \text{Clip3}(\,0,\,(\,1 \ll \text{bitDepth}\,) - 1,\,(\,\text{predSamplesL1}[\,x\,][\,y\,] + \text{offset1}\,) \gg \text{shift1}\,) \quad (8\text{-}238)$$

– Otherwise (predFlagL0 is equal to 1 and predFlagL1 is equal to 1), the prediction sample values are derived as follows:

$$\begin{aligned}\text{predSamples}[\,x\,][\,y\,] = \text{Clip3}(\,0,\,&(\,1 \ll \text{bitDepth}\,) - 1,\\ &(\,\text{predSamplesL0}[\,x\,][\,y\,] + \text{predSamplesL1}[\,x\,][\,y\,] + \text{offset2}\,) \gg \text{shift2}\,)\end{aligned} \quad (8\text{-}239)$$

### 8.5.3.3.4.3 Explicit weighted sample prediction process

Inputs to this process are:

– two variables nPbW and nPbH specifying the width and the height of the luma prediction block,

– two (nPbW)x(nPbH) arrays predSamplesL0 and predSamplesL1,

– the prediction list utilization flags, predFlagL0, and predFlagL1,

– the reference indices, refIdxL0 and refIdxL1,

– a variable cIdx specifying colour component index,

– a bit depth of samples, bitDepth.

Output of this process is the (nPbW)x(nPbH) array predSamples of prediction sample values.

The variable shift1 is set equal to 14 − bitDepth.

The variables log2Wd, o0, o1, and w0, w1 are derived as follows:

– If cIdx is equal to 0 for luma samples, the following applies:

$$\text{log2Wd} = \text{luma\_log2\_weight\_denom} + \text{shift1} \quad (8\text{-}240)$$

$$\text{w0} = \text{LumaWeightL0}[\ \text{refIdxL0}\ ] \quad (8\text{-}241)$$

$$\text{w1} = \text{LumaWeightL1}[\ \text{refIdxL1}\ ] \quad (8\text{-}242)$$

$$\text{o0} = \text{luma\_offset\_l0}[\ \text{refIdxL0}\ ] * (\ 1 \ll (\ \text{bitDepth} - 8\ )\ ) \quad (8\text{-}243)$$

$$\text{o1} = \text{luma\_offset\_l1}[\ \text{refIdxL1}\ ] * (\ 1 \ll (\ \text{bitDepth} - 8\ )\ ) \quad (8\text{-}244)$$

– Otherwise (cIdx is not equal to 0 for chroma samples), the following applies:

$$\text{log2Wd} = \text{ChromaLog2WeightDenom} + \text{shift1} \quad (8\text{-}245)$$

$$\text{w0} = \text{ChromaWeightL0}[\ \text{refIdxL0}\ ][\ \text{cIdx} - 1\ ] \quad (8\text{-}246)$$

$$\text{w1} = \text{ChromaWeightL1}[\ \text{refIdxL1}\ ][\ \text{cIdx} - 1\ ] \quad (8\text{-}247)$$

$$\text{o0} = \text{ChromaOffsetL0}[\ \text{refIdxL0}\ ][\ \text{cIdx} - 1\ ] * (\ 1 \ll (\ \text{bitDepth} - 8\ )\ ) \quad (8\text{-}248)$$

$$\text{o1} = \text{ChromaOffsetL1}[\ \text{refIdxL1}\ ][\ \text{cIdx} - 1\ ] * (\ 1 \ll (\ \text{bitDepth} - 8\ )\ ) \quad (8\text{-}249)$$

The prediction sample predSamples[ x ][ y ] with x = 0..nPbW − 1 and y = 0..nPbH − 1 are derived as follows:

– If the predFlagL0 is equal to 1 and predFlagL1 is equal to 0, the prediction sample values are derived as follows:

```
if( log2Wd >= 1 )
        predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1,
             ( ( predSamplesL0[ x ][ y ] * w0 + $2^{\text{log2Wd} - 1}$ ) >> log2Wd ) + o0 )        (8-250)
else
        predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1, predSamplesL0[ x ][ y ] * w0 + o0 )
```

– Otherwise, if the predFlagL0 is equal to 0 and predFlagL1 is equal to 1, the prediction sample values are derived as follows:

```
if( log2Wd >= 1 )
        predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1,
             ( ( predSamplesL1[ x ][ y ] * w1 + $2^{\text{log2Wd} - 1}$ ) >> log2Wd ) + o1 )        (8-251)
else
        predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1, predSamplesL1[ x ][ y ] * w1 + o1 )
```

– Otherwise (predFlagL0 is equal to 1 and predFlagL1 is equal to 1), the prediction sample values are derived as follows:

```
predSamples[ x ][ y ] = Clip3( 0, ( 1 << bitDepth ) − 1,
        ( predSamplesL0 [ x ][ y ] * w0 + predSamplesL1[ x ][ y ] * w1 +
             ( ( o0 + o1 + 1 ) << log2Wd ) ) >> ( log2Wd + 1 ) )        (8-252)
```

### 8.5.4 Decoding process for the residual signal of coding units coded in inter prediction mode

#### 8.5.4.1 General

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current luma coding block.

Outputs of this process are:

– an $(nCbS_L)x(nCbS_L)$ array $resSamples_L$ of luma residual samples, where $nCbS_L$ is derived as specified below,

– an $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cb}$ of chroma residual samples for the component Cb, where $nCbS_C$ is derived as specified below,

– an $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cr}$ of chroma residual samples for the component Cr, where $nCbS_C$ is derived as specified below.

The variable $nCbS_L$ is set equal to 1 << log2CbSize and the variable $nCbS_C$ is set equal to $nCbS_L$ >> 1.

Let $resSamples_L$ be an $(nCbS_L)x(nCbS_L)$ array of luma residual samples and let $resSamples_{Cb}$ and $resSamples_{Cr}$ be two $(nCbS_C)x(nCbS_C)$ arrays of chroma residual samples.

Depending on the value of rqt_root_cbf, the following applies:

– If rqt_root_cbf is equal to 0 or skip_flag[ xCb ][ yCb ] is equal to 1, all samples of the $(nCbS_L)x(nCbS_L)$ array $resSamples_L$ and all samples of the two $(nCbS_C)x(nCbS_C)$ arrays $resSamples_{Cb}$ and $resSamples_{Cr}$ are set equal to 0.

– Otherwise (rqt_root_cbf is equal to 1), the following ordered steps apply:

1. The decoding process for luma residual blocks as specified in subclause 8.5.4.2 below is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ) set equal to ( 0, 0 ), the variable log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable nCbS set equal to $nCbS_L$, and the $(nCbS_L)x(nCbS_L)$ array $resSamples_L$ as inputs, and the output is a modified version of the $(nCbS_L)x(nCbS_L)$ array $resSamples_L$.

2. The decoding process for chroma residual blocks as specified in subclause 8.5.4.3 below is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ) set equal to ( 0, 0 ), the variable log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable cIdx set equal to 1, the variable nCbS set equal to $nCbS_C$, and the $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cb}$ as inputs, and the output is a modified version of the $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cb}$.

3. The decoding process for chroma residual blocks as specified in subclause 8.5.4.3 below is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ) set equal to ( 0, 0 ), the variable log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable cIdx set equal to 2, the variable nCbS set equal to $nCbS_C$, and the $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cr}$ as inputs, and the output is a modified version of the $(nCbS_C)x(nCbS_C)$ array $resSamples_{Cr}$.

### 8.5.4.2 Decoding process for luma residual blocks

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xB0, yB0 ) specifying the top-left sample of the current luma block relative to the top-left sample of the current luma coding block,

– a variable log2TrafoSize specifying the size of the current luma block,

– a variable trafoDepth specifying the hierarchy depth of the current luma block relative to the luma coding block,

– a variable nCbS specifying the size of the current luma coding block,

– an (nCbS)x(nCbS) array resSamples of luma residual samples.

Output of this process is a modified version of the (nCbS)x(nCbS) array of luma residual samples.

Depending on the value of split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ], the following applies:

– If split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 1, the following ordered steps apply:

1. The variables xB1 and yB1 are derived as follows:

   – The variable xB1 is set equal to xB0 + ( 1 << ( log2TrafoSize − 1 ) ).

   – The variable yB1 is set equal to yB0 + ( 1 << ( log2TrafoSize − 1 ) ).

2. The decoding process for luma residual blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

3. The decoding process for luma residual blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.
4. The decoding process for luma residual blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.
5. The decoding process for luma residual blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

– Otherwise (split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 0), the following ordered steps apply:
  1. The variable nTbS is set equal to 1 << log2TrafoSize.
  2. The scaling and transformation process as specified in subclause 8.6.2 is invoked with the luma location ( xCb + xB0, yCb + yB0 ), the variable trafoDepth, the variable cIdx set equal to 0, and the transform size trafoSize set equal to nTbS as inputs, and the output is an (nTbS)x(nTbS) array transformBlock.
  3. The (nCbS)x(nCbS) residual sample array of the current coding block resSamples is modified as follows:

$$\text{resSamples}[\ xB0 + i,\ yB0 + j\ ] = \text{transformBlock}[\ i, j\ ],\ \text{with } i = 0..nTbS - 1,\ j = 0..nTbS - 1 \qquad (8\text{-}253)$$

### 8.5.4.3 Decoding process for chroma residual blocks

Inputs to this process are:

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,
– a luma location ( xB0, yB0 ) specifying the top-left luma sample of the current chroma block relative to the top-left sample of the current luma coding block,
– a variable log2TrafoSize specifying the size of the current chroma block in luma samples,
– a variable trafoDepth specifying the hierarchy depth of the current chroma block relative to the chroma coding block,
– a variable cIdx specifying the chroma component of the current block,
– a variable nCbS specifying the size of the current chroma coding block,
– an (nCbS)x(nCbS) array resSamples of chroma residual samples.

Output of this process is a modified version of the (nCbS)x(nCbS) array of chroma residual samples.

The variable splitChromaFlag is derived as follows:

– If split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 1 and log2TrafoSize is greater than 3, splitChromaFlag is set equal to 1.
– Otherwise (split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 0 or log2TrafoSize is equal to 3), splitChromaFlag is set equal to 0.

Depending on the value of splitChromaFlag, the following applies:

– If splitChromaFlag is equal to 1, the following ordered steps apply:
  1. The variables xB1 and yB1 are derived as follows:
     – The variable xB1 is set equal to xB0 + ( 1 << ( log2TrafoSize − 1 ) ).
     – The variable yB1 is set equal to yB0 + ( 1 << ( log2TrafoSize − 1 ) ).
  2. The decoding process for residual chroma blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable cIdx, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

3. The decoding process for residual chroma blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable cIdx, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

4. The decoding process for residual chroma blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable cIdx, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

5. The decoding process for residual chroma blocks as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable cIdx, the variable nCbS, and the (nCbS)x(nCbS) array resSamples as inputs, and the output is a modified version of the (nCbS)x(nCbS) array resSamples.

– Otherwise (splitChromaFlag is equal to 0), the following ordered steps apply:

1. The variable nTbS is set equal to 1 << ( log2TrafoSize − 1 ).

2. The scaling and transformation process as specified in subclause 8.6.2 is invoked with the luma location ( xCb + xB0, yCb + yB0 ), the variable trafoDepth, the variable cIdx, and the transform size trafoSize set equal to nTbS as inputs, and the output is an (nTbS)x(nTbS) array transformBlock.

3. The (nCbS)x(nCbS) residual sample array of the current coding block resSamples is modified as follows, for i = 0..nTbS − 1, j = 0..nTbS − 1:

   resSamples[ ( xCb + xB0 ) / 2 + i, ( yCb + yB0 ) / 2 + j ] = transformBlock[ i, j ] (8-254)

## 8.6 Scaling, transformation and array construction process prior to deblocking filter process

### 8.6.1 Derivation process for quantization parameters

Input to this process is a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture.

In this process, the variable $\mathrm{Qp}_\mathrm{Y}$, the luma quantization parameter $\mathrm{Qp}'_\mathrm{Y}$, and the chroma quantization parameters $\mathrm{Qp}'_\mathrm{Cb}$ and $\mathrm{Qp}'_\mathrm{Cr}$ are derived.

The luma location ( xQg, yQg ), specifies the top-left luma sample of the current quantization group relative to the top-left luma sample of the current picture. The horizontal and vertical positions xQg and yQg are set equal to xCb − ( xCb & ( ( 1 << Log2MinCuQpDeltaSize) − 1 ) ) and yCb − ( yCb & ( ( 1 << Log2MinCuQpDeltaSize) − 1 ) ), respectively. The luma size of a quantization group, Log2MinCuQpDeltaSize, determines the luma size of the smallest area inside a coding tree block that shares the same $\mathrm{qP}_\mathrm{Y\_PRED}$.

The predicted luma quantization parameter $\mathrm{qP}_\mathrm{Y\_PRED}$ is derived by the following ordered steps:

1. The variable $\mathrm{qP}_\mathrm{Y\_PREV}$ is derived as follows:
   - If one or more of the following conditions are true, $\mathrm{qP}_\mathrm{Y\_PREV}$ is set equal to $\mathrm{SliceQp}_\mathrm{Y}$:
     - The current quantization group is the first quantization group in a slice.
     - The current quantization group is the first quantization group in a tile.
     - The current quantization group is the first quantization group in a coding tree block row and entropy_coding_sync_enabled_flag is equal to 1.
   - Otherwise, $\mathrm{qP}_\mathrm{Y\_PREV}$ is set equal to the luma quantization parameter $\mathrm{Qp}_\mathrm{Y}$ of the last coding unit in the previous quantization group in decoding order.

2. The availability derivation process for a block in z-scan order as specified in subclause 6.4.1 is invoked with the location ( xCurr, yCurr ) set equal to ( xCb, yCb ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xQg − 1, yQg ) as inputs, and the output is assigned to availableA. The variable $\mathrm{qP}_\mathrm{Y\_A}$ is derived as follows:
   - If one or more of the following conditions are true, $\mathrm{qP}_\mathrm{Y\_A}$ is set equal to $\mathrm{qP}_\mathrm{Y\_PREV}$:
     - availableA is equal to FALSE.
     - the coding tree block address ctbAddrA of the coding tree block containing the luma coding block covering the luma location ( xQg − 1, yQg ) is not equal to CtbAddrInTs, where ctbAddrA is derived as follows:

$$\begin{aligned}&xTmp = ( xQg - 1 ) >> Log2MinTrafoSize\\&yTmp = yQg >> Log2MinTrafoSize\\&minTbAddrA = MinTbAddrZs[ xTmp ][ yTmp ]\\&ctbAddrA = ( minTbAddrA >> 2 ) * (CtbLog2SizeY - Log2MinTrafoSize)\end{aligned} \quad (8\text{-}255)$$

– Otherwise, $qP_{Y\_A}$ is set equal to the luma quantization parameter $Qp_Y$ of the coding unit containing the luma coding block covering ( xQg − 1, yQg ).

3. The availability derivation process for a block in z-scan order as specified in subclause 6.4.1 is invoked with the location ( xCurr, yCurr ) set equal to ( xCb, yCb ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xQg, yQg − 1 ) as inputs, and the output is assigned to availableB. The variable $qP_{Y\_B}$ is derived as follows:

   – If one or more of the following conditions are true, $qP_{Y\_B}$ is set equal to $qP_{Y\_PREV}$:

     – availableB is equal to FALSE.

     – the coding tree block address ctbAddrB of the coding tree block containing the luma coding block covering the luma location ( xQg, yQg − 1 ) is not equal to CtbAddrInTs, where ctbAddrB is derived as follows:

$$\begin{aligned}&xTmp = xQg >> Log2MinTrafoSize\\&yTmp = ( yQg - 1 ) >> Log2MinTrafoSize\\&minTbAddrB = MinTbAddrZs[ xTmp ][ yTmp ]\\&ctbAddrB = ( minTbAddrB >> 2 ) * (CtbLog2SizeY - Log2MinTrafoSize)\end{aligned} \quad (8\text{-}256)$$

   – Otherwise, $qP_{Y\_B}$ is set equal to the luma quantization parameter $Qp_Y$ of the coding unit containing the luma coding block covering ( xQg, yQg − 1 ).

4. The predicted luma quantization parameter $qP_{Y\_PRED}$ is derived as follows:

$$qP_{Y\_PRED} = ( qP_{Y\_A} + qP_{Y\_B} + 1 ) >> 1 \quad (8\text{-}257)$$

The variable $Qp_Y$ is derived as follows:

$$Qp_Y = ( ( qP_{Y\_PRED} + CuQpDeltaVal + 52 + 2 * QpBdOffset_Y )\%( 52 + QpBdOffset_Y ) ) - QpBdOffset_Y \quad (8\text{-}258)$$

The luma quantization parameter $Qp'_Y$ is derived as follows:

$$Qp'_Y = Qp_Y + QpBdOffset_Y \quad (8\text{-}259)$$

The variables $qP_{Cb}$ and $qP_{Cr}$ are set equal to the value of $Qp_C$ as specified in Table 8-9 based on the index qPi equal to $qPi_{Cb}$ and $qPi_{Cr}$, respectively, and $qPi_{Cb}$ and $qPi_{Cr}$ are derived as follows:

$$qPi_{Cb} = Clip3( -QpBdOffset_C, 57, Qp_Y + pps\_cb\_qp\_offset + slice\_cb\_qp\_offset ) \quad (8\text{-}260)$$

$$qPi_{Cr} = Clip3( -QpBdOffset_C, 57, Qp_Y + pps\_cr\_qp\_offset + slice\_cr\_qp\_offset ) \quad (8\text{-}261)$$

The chroma quantization parameters for the Cb and Cr components, $Qp'_{Cb}$ and $Qp'_{Cr}$, are derived as follows:

$$Qp'_{Cb} = qP_{Cb} + QpBdOffset_C \quad (8\text{-}262)$$

$$Qp'_{Cr} = qP_{Cr} + QpBdOffset_C \quad (8\text{-}263)$$

**Table 8-9 – Specification of $Qp_C$ as a function of qPi**

| qPi | < 30 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | > 43 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $Qp_C$ | = qPi | 29 | 30 | 31 | 32 | 33 | 33 | 34 | 34 | 35 | 35 | 36 | 36 | 37 | 37 | = qPi − 6 |

### 8.6.2 Scaling and transformation process

Inputs to this process are:

– a luma location ( xTbY, yTbY ) specifying the top-left sample of the current luma transform block relative to the top-left luma sample of the current picture,

– a variable trafoDepth specifying the hierarchy depth of the current block relative to the coding block,

– a variable cIdx specifying the colour component of the current block,

– a variable nTbS specifying the size of the current transform block.

Output of this process is the (nTbS)x(nTbS) array of residual samples r with elements r[ x ][ y ].

The quantization parameter qP is derived as follows:

– If cIdx is equal to 0,

$$qP = Qp'_Y \tag{8-264}$$

– Otherwise, if cIdx is equal to 1,

$$qP = Qp'_{Cb} \tag{8-265}$$

– Otherwise (cIdx is equal to 2),

$$qP = Qp'_{Cr} \tag{8-266}$$

The (nTbS)x(nTbS) array of residual samples r is derived as follows:

– If cu_transquant_bypass_flag is equal to 1, the (nTbS)x(nTbS) array r is set equal to the (nTbS)x(nTbS) array of transform coefficients TransCoeffLevel[ xTbY ][ yTbY ][ cIdx ].

– Otherwise, the following ordered steps apply:

1. The scaling process for transform coefficients as specified in subclause 8.6.3 is invoked with the transform block location ( xTbY, yTbY ), the size of the transform block nTbS, the colour component variable cIdx, and the quantization parameter qP as inputs, and the output is an (nTbS)x(nTbS) array of scaled transform coefficients d.

2. The (nTbS)x(nTbS) array of residual samples r is derived as follows:

   – If transform_skip_flag[ xTbY ][ yTbY ][ cIdx ] is equal to 1, the residual sample array values r[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 are derived as follows:

   $$r[\,x\,][\,y\,] = (\,d[\,x\,][\,y\,] \ll 7\,) \tag{8-267}$$

   – Otherwise (transform_skip_flag[ xTbY ][ yTbY ][ cIdx ] is equal to 0), the transformation process for scaled transform coefficients as specified in subclause 8.6.4 is invoked with the transform block location ( xTbY, yTbY ), the size of the transform block nTbS, the colour component variable cIdx, and the (nTbS)x(nTbS) array of scaled transform coefficients d as inputs, and the output is an (nTbS)x(nTbS) array of residual samples r.

3. The variable bdShift is derived as follows:

   $$bdShift = (\,cIdx == 0\,)\ ?\ 20 - BitDepth_Y : 20 - BitDepth_C \tag{8-268}$$

4. The residual sample values r[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 are modified as follows:

   $$r[\,x\,][\,y\,] = (\,r[\,x\,][\,y\,] + (\,1 \ll (\,bdShift - 1\,)\,)\,) \gg bdShift \tag{8-269}$$

### 8.6.3 Scaling process for transform coefficients

Inputs to this process are:

– a luma location ( xTbY, yTbY ) specifying the top-left sample of the current luma transform block relative to the top-left luma sample of the current picture,

– a variable nTbS specifying the size of the current transform block,

– a variable cIdx specifying the colour component of the current block,

– a variable qP specifying the quantization parameter.

Output of this process is the (nTbS)x(nTbS) array d of scaled transform coefficients with elements d[ x ][ y ].

The variable bdShift is derived as follows:

– If cIdx is equal to 0,

$$bdShift = BitDepth_Y + Log2(\,nTbS\,) - 5 \tag{8-270}$$

– Otherwise,

$$bdShift = BitDepth_C + Log2(\,nTbS\,) - 5 \tag{8-271}$$

The list levelScale[ ] is specified as levelScale[ k ] = { 40, 45, 51, 57, 64, 72 } with k = 0..5.

For the derivation of the scaled transform coefficients d[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1, the following applies:

– The scaling factor m[ x ][ y ] is derived as follows:

  – If scaling_list_enabled_flag is equal to 0,

$$m[\,x\,][\,y\,] = 16 \qquad (8\text{-}272)$$

  – Otherwise (scaling_list_enabled_flag is equal to 1),

$$m[\,x\,][\,y\,] = \text{ScalingFactor}[\,\text{sizeId}\,][\,\text{matrixId}\,][\,x\,][\,y\,] \qquad (8\text{-}273)$$

Where sizeId is specified in Table 7-3 for the size of the quantization matrix equal to (nTbS)x(nTbS) and matrixId is specified in Table 7-4 for sizeId, CuPredMode[ xTbY ][ yTbY ], and cIdx, respectively.

– The scaled transform coefficient d[ x ][ y ] is derived as follows:

$$d[\,x\,][\,y\,] = \text{Clip3}(\,-32768, 32767, (\,(\,\text{TransCoeffLevel}[\,\text{xTbY}\,][\,\text{yTbY}\,][\,\text{cIdx}\,][\,x\,][\,y\,] * m[\,x\,][\,y\,] * \text{levelScale}[\,\text{qP}\%6\,] \ll (\text{qP} / 6\,)\,) + (\,1 \ll (\,\text{bdShift} - 1\,)\,)\,) \gg \text{bdShift}\,) \qquad (8\text{-}274)$$

### 8.6.4 Transformation process for scaled transform coefficients

#### 8.6.4.1 General

Inputs to this process are:

– a luma location ( xTbY, yTbY ) specifying the top-left sample of the current luma transform block relative to the top-left luma sample of the current picture,

– a variable nTbS specifying the size of the current transform block,

– a variable cIdx specifying the colour component of the current block,

– an (nTbS)x(nTbS) array d of scaled transform coefficients with elements d[ x ][ y ].

Output of this process is the (nTbS)x(nTbS) array r of residual samples with elements r[ x ][ y ].

Depending on the values of CuPredMode[ xTbY ][ yTbY ], nTbS, and cIdx, the variable trType is derived as follows:

– If CuPredMode[ xTbY ][ yTbY ] is equal to MODE_INTRA, nTbS is equal to 4, and cIdx is equal to 0, trType is set equal to 1.

– Otherwise, trType is set equal to 0.

The (nTbS)x(nTbS) array r of residual samples is derived as follows:

1. Each (vertical) column of scaled transform coefficients d[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 is transformed to e[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 by invoking the one-dimensional transformation process as specified in subclause 8.6.4.2 for each column x = 0..nTbS − 1 with the size of the transform block nTbS, the list d[ x ][ y ] with y = 0..nTbS − 1, and the transform type variable trType as inputs, and the output is the list e[ x ][ y ] with y = 0..nTbS − 1.

2. The intermediate sample values g[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 are derived as follows:

$$g[\,x\,][\,y\,] = \text{Clip3}(\,-32768, 32767, (\,e[\,x\,][\,y\,] + 64\,) \gg 7\,) \qquad (8\text{-}275)$$

3. Each (horizontal) row of the resulting array g[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 is transformed to r[ x ][ y ] with x = 0..nTbS − 1, y = 0..nTbS − 1 by invoking the one-dimensional transformation process as specified in subclause 8.6.4.2 for each row y = 0..nTbS − 1 with the size of the transform block nTbS, the list g[ x ][ y ] with x = 0..nTbS − 1, and the transform type variable trType as inputs, and the output is the list r[ x ][ y ] with x = 0..nTbS − 1.

#### 8.6.4.2 Transformation process

Inputs to this process are:

– a variable nTbS specifying the sample size of scaled transform coefficients,

– a list of scaled transform coefficients x with elements x[ j ], with j = 0..nTbS − 1.

– a transform type variable trType

Output of this process is the list of transformed samples y with elements y[ i ], with i = 0..nTbS − 1.

Depending on the value of trType, the following applies:

– If trType is equal to 1, the following transform matrix multiplication applies:

$$y[\,i\,] = \sum_{j=0}^{nTbS-1} transMatrix[i][j] * x[j] \text{ with } i = 0..nTbS - 1 \qquad (8\text{-}276)$$

where the transform coefficient array transMatrix is specified as follows:

transMatrix = (8-277)

```
{
{29  55  74  84}
{74  74   0 -74}
{84 -29 -74  55}
{55 -84  74 -29}
}
```

– Otherwise (trType is equal to 0), the following transform matrix multiplication applies:

$$y[\,i\,] = \sum_{j=0}^{nTbS-1} transMatrix[i][j * 2^{5-Log2(nTbS)}] * x[j] \text{ with } i = 0..nTbS - 1, \qquad (8\text{-}278)$$

where the transform coefficient array transMatrix is specified as follows:

transMatrix[ m ][ n ] = transMatrixCol0to15[ m ][ n ] with m = 0..15, n = 0..31 (8-279)

transMatrixCol0to15 = (8-280)

```
{
{64  64  64  64  64  64  64  64  64  64  64  64  64  64  64  64}
{90  90  88  85  82  78  73  67  61  54  46  38  31  22  13   4}
{90  87  80  70  57  43  25   9  -9 -25 -43 -57 -70 -80 -87 -90}
{90  82  67  46  22  -4 -31 -54 -73 -85 -90 -88 -78 -61 -38 -13}
{89  75  50  18 -18 -50 -75 -89 -89 -75 -50 -18  18  50  75  89}
{88  67  31 -13 -54 -82 -90 -78 -46  -4  38  73  90  85  61  22}
{87  57   9 -43 -80 -90 -70 -25  25  70  90  80  43  -9 -57 -87}
{85  46 -13 -67 -90 -73 -22  38  82  88  54  -4 -61 -90 -78 -31}
{83  36 -36 -83 -83 -36  36  83  83  36 -36 -83 -83 -36  36  83}
{82  22 -54 -90 -61  13  78  85  31 -46 -90 -67   4  73  88  38}
{80   9 -70 -87 -25  57  90  43 -43 -90 -57  25  87  70  -9 -80}
{78  -4 -82 -73  13  85  67 -22 -88 -61  31  90  54 -38 -90 -46}
{75 -18 -89 -50  50  89  18 -75 -75  18  89  50 -50 -89 -18  75}
{73 -31 -90 -22  78  67 -38 -90 -13  82  61 -46 -88  -4  85  54}
{70 -43 -87   9  90  25 -80 -57  57  80 -25 -90  -9  87  43 -70}
{67 -54 -78  38  85 -22 -90   4  90  13 -88 -31  82  46 -73 -61}
{64 -64 -64  64  64 -64 -64  64  64 -64 -64  64  64 -64 -64  64}
{61 -73 -46  82  31 -88 -13  90  -4 -90  22  85 -38 -78  54  67}
{57 -80 -25  90  -9 -87  43  70 -70 -43  87   9 -90  25  80 -57}
{54 -85  -4  88 -46 -61  82  13 -90  38  67 -78 -22  90 -31 -73}
{50 -89  18  75 -75 -18  89 -50 -50  89 -18 -75  75  18 -89  50}
{46 -90  38  54 -90  31  61 -88  22  67 -85  13  73 -82   4  78}
{43 -90  57  25 -87  70   9 -80  80  -9 -70  87 -25 -57  90 -43}
{38 -88  73  -4 -67  90 -46 -31  85 -78  13  61 -90  54  22 -82}
{36 -83  83 -36 -36  83 -83  36  36 -83  83 -36 -36  83 -83  36}
{31 -78  90 -61   4  54 -88  82 -38 -22  73 -90  67 -13 -46  85}
{25 -70  90 -80  43   9 -57  87 -87  57  -9 -43  80 -90  70 -25}
{22 -61  85 -90  73 -38  -4  46 -78  90 -82  54 -13 -31  67 -88}
{18 -50  75 -89  89 -75  50 -18 -18  50 -75  89 -89  75 -50  18}
{13 -38  61 -78  88 -90  85 -73  54 -31   4  22 -46  67 -82  90}
{ 9 -25  43 -57  70 -80  87 -90  90 -87  80 -70  57 -43  25  -9}
{ 4 -13  22 -31  38 -46  54 -61  67 -73  78 -82  85 -88  90 -90}
},
```

transMatrix[ m ][ n ] = transMatrixCol16to31[ m − 16 ][ n ] with m = 16..31, n = 0..31, (8-281)

transMatrixCol16to31 = (8-282)

```
{
{ 64  64  64  64  64  64  64  64  64  64  64  64  64  64  64  64}
{ -4 -13 -22 -31 -38 -46 -54 -61 -67 -73 -78 -82 -85 -88 -90 -90}
{-90 -87 -80 -70 -57 -43 -25  -9   9  25  43  57  70  80  87  90}
{ 13  38  61  78  88  90  85  73  54  31   4 -22 -46 -67 -82 -90}
{ 89  75  50  18 -18 -50 -75 -89 -89 -75 -50 -18  18  50  75  89}
{-22 -61 -85 -90 -73 -38   4  46  78  90  82  54  13 -31 -67 -88}
{-87 -57  -9  43  80  90  70  25 -25 -70 -90 -80 -43   9  57  87}
{ 31  78  90  61   4 -54 -88 -82 -38  22  73  90  67  13 -46 -85}
{ 83  36 -36 -83 -83 -36  36  83  83  36 -36 -83 -83 -36  36  83}
{-38 -88 -73  -4  67  90  46 -31 -85 -78 -13  61  90  54 -22 -82}
{-80  -9  70  87  25 -57 -90 -43  43  90  57 -25 -87 -70   9  80}
{ 46  90  38 -54 -90 -31  61  88  22 -67 -85 -13  73  82   4 -78}
{ 75 -18 -89 -50  50  89  18 -75 -75  18  89  50 -50 -89 -18  75}
{-54 -85   4  88  46 -61 -82  13  90  38 -67 -78  22  90  31 -73}
{-70  43  87  -9 -90 -25  80  57 -57 -80  25  90   9 -87 -43  70}
{ 61  73 -46 -82  31  88 -13 -90  -4  90  22 -85 -38  78  54 -67}
{ 64 -64 -64  64  64 -64 -64  64  64 -64 -64  64  64 -64 -64  64}
{-67 -54  78  38 -85 -22  90   4 -90  13  88 -31 -82  46  73 -61}
{-57  80  25 -90   9  87 -43 -70  70  43 -87  -9  90 -25 -80  57}
{ 73  31 -90  22  78 -67 -38  90 -13 -82  61  46 -88   4  85 -54}
{ 50 -89  18  75 -75 -18  89 -50 -50  89 -18 -75  75  18 -89  50}
{-78  -4  82 -73 -13  85 -67 -22  88 -61 -31  90 -54 -38  90 -46}
{-43  90 -57 -25  87 -70  -9  80 -80   9  70 -87  25  57 -90  43}
{ 82 -22 -54  90 -61 -13  78 -85  31  46 -90  67   4 -73  88 -38}
{ 36 -83  83 -36 -36  83 -83  36  36 -83  83 -36 -36  83 -83  36}
{-85  46  13 -67  90 -73  22  38 -82  88 -54  -4  61 -90  78 -31}
{-25  70 -90  80 -43  -9  57 -87  87 -57   9  43 -80  90 -70  25}
{ 88 -67  31  13 -54  82 -90  78 -46   4  38 -73  90 -85  61 -22}
{ 18 -50  75 -89  89 -75  50 -18 -18  50 -75  89 -89  75 -50  18}
{-90  82 -67  46 -22  -4  31 -54  73 -85  90 -88  78 -61  38 -13}
{ -9  25 -43  57 -70  80 -87  90 -90  87 -80  70 -57  43 -25   9}
{ 90 -90  88 -85  82 -78  73 -67  61 -54  46 -38  31 -22  13  -4}
}
```

### 8.6.5 Picture construction process prior to in-loop filter process

Inputs to this process are:

– a location ( xCurr, yCurr ) specifying the top-left sample of the current block relative to the top-left sample of the current picture component,

– a variable nCurrS specifying the size of the current block,

– a variable cIdx specifying the colour component of the current block,

– an (nCurrS)x(nCurrS) array predSamples specifying the predicted samples of the current block,

– an (nCurrS)x(nCurrS) array resSamples specifying the residual samples of the current block.

Depending on the value of the colour component cIdx, the following assignments are made:

– If cIdx is equal to 0, recSamples corresponds to the reconstructed picture sample array $S_L$ and the function clipCidx1 corresponds to $Clip1_Y$.

– Otherwise, if cIdx is equal to 1, recSamples corresponds to the reconstructed chroma sample array $S_{Cb}$ and the function clipCidx1 corresponds to $Clip1_C$.

– Otherwise (cIdx is equal to 2), recSamples corresponds to the reconstructed chroma sample array $S_{Cr}$ and the function clipCidx1 corresponds to $Clip1_C$.

The (nCurrS)x(nCurrS) block of the reconstructed sample array recSamples at location ( xCurr, yCurr ) is derived as follows:

recSamples[ xCurr + i ][ yCurr + j ] = clipCidx1( predSamples[ i ][ j ] + resSamples[ i ][ j ] ) (8-283)
with i = 0..nCurrS − 1, j = 0..nCurrS − 1

## 8.7 In-loop filter process

### 8.7.1 General

The two in-loop filters, namely deblocking filter and sample adaptive offset filter, are applied as specified by the following ordered steps:

1. For the deblocking filter, the following applies:
   – The deblocking filter process as specified in subclause 8.7.2 is invoked with the reconstructed picture sample arrays $S_L$, $S_{Cb}$, and $S_{Cr}$ as inputs, and the modified reconstructed picture sample arrays $S'_L$, $S'_{Cb}$, and $S'_{Cr}$ after deblocking as outputs.
   – The arrays $S'_L$, $S'_{Cb}$, $S'_{Cr}$ are assigned to the arrays $S_L$, $S_{Cb}$, $S_{Cr}$ (which represent the decoded picture), respectively.
2. When sample_adaptive_offset_enabled_flag is equal to 1, the following applies:
   – The sample adaptive offset process as specified in subclause 8.7.3 is invoked with the reconstructed picture sample arrays $S_L$, $S_{Cb}$, and $S_{Cr}$ as inputs, and the modified reconstructed picture sample arrays $S'_L$, $S'_{Cb}$, and $S'_{Cr}$ after sample adaptive offset as outputs.
   – The arrays $S'_L$, $S'_{Cb}$, $S'_{Cr}$ are assigned to the arrays $S_L$, $S_{Cb}$, $S_{Cr}$ (which represent the decoded picture), respectively.

## 8.7.2 Deblocking filter process

### 8.7.2.1 General

Inputs to this process are the reconstructed picture sample arrays prior to deblocking $recPicture_L$, $recPicture_{Cb}$, and $recPicture_{Cr}$.

Outputs of this process are the modified reconstructed picture sample arrays after deblocking $recPicture_L$, $recPicture_{Cb}$, and $recPicture_{Cr}$.

The vertical edges in a picture are filtered first. Then the horizontal edges in a picture are filtered with samples modified by the vertical edge filtering process as input. The vertical and horizontal edges in the coding tree blocks of each coding tree unit are processed separately on a coding unit basis. The vertical edges of the coding blocks in a coding unit are filtered starting with the edge on the left-hand side of the coding blocks proceeding through the edges towards the right-hand side of the coding blocks in their geometrical order. The horizontal edges of the coding blocks in a coding unit are filtered starting with the edge on the top of the coding blocks proceeding through the edges towards the bottom of the coding blocks in their geometrical order.

NOTE – Although the filtering process is specified on a picture basis in this specification, the filtering process can be implemented on a coding unit basis with an equivalent result, provided the decoder properly accounts for the processing dependency order so as to produce the same output values.

The deblocking filter process is applied to all prediction block edges and transform block edges of a picture, except the edges that are at the boundary of the picture, for which the deblocking filter process is disabled by slice_deblocking_filter_disabled_flag, that coincide with tile boundaries when loop_filter_across_tiles_enabled_flag is equal to 0, or that coincide with upper or left slice boundaries of slices with slice_loop_filter_across_slices_enabled_flag equal to 0. For the transform units and prediction units with luma block edges less than 8 samples in either vertical or horizontal direction, only the edges lying on the 8x8 sample grid are filtered.

The edge type, vertical or horizontal, is represented by the variable edgeType as specified in Table 8-10.

**Table 8-10 – Name of association to edgeType**

| edgeType | Name of edgeType |
|---|---|
| 0 (vertical edge) | EDGE_VER |
| 1 (horizontal edge) | EDGE_HOR |

When slice_deblocking_filter_disabled_flag of the current slice is equal to 0, for each coding unit with luma coding block size log2CbSize and location of top-left sample of the luma coding block ( xCb, yCb ), the vertical edges are filtered by the following ordered steps:

1. The luma coding block size nCbS is set equal to 1 << log2CbSize.
2. The variable filterLeftCbEdgeFlag is derived as follows:
   – If one or more of the following conditions are true, filterLeftCbEdgeFlag is set equal to 0:
     – The left boundary of the current luma coding block is the left boundary of the picture.
     – The left boundary of the current luma coding block is the left boundary of the tile and loop_filter_across_tiles_enabled_flag is equal to 0.

    – The left boundary of the current luma coding block is the left boundary of the slice and slice_loop_filter_across_slices_enabled_flag is equal to 0.

  – Otherwise, filterLeftCbEdgeFlag is set equal to 1.

3. All elements of the two-dimensional (nCbS)x(nCbS) array verEdgeFlags are initialized to be equal to zero.

4. The derivation process of transform block boundary specified in subclause 8.7.2.2 is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ) set equal to ( 0, 0 ), the transform block size log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable filterLeftCbEdgeFlag, the array verEdgeFlags, and the variable edgeType set equal to EDGE_VER as inputs, and the modified array verEdgeFlags as output.

5. The derivation process of prediction block boundary specified in subclause 8.7.2.3 is invoked with the luma coding block size log2CbSize, the prediction partition mode PartMode, the array verEdgeFlags, and the variable edgeType set equal to EDGE_VER as inputs, and the modified array verEdgeFlags as output.

6. The derivation process of the boundary filtering strength specified in subclause 8.7.2.4 is invoked with the reconstructed luma picture sample array prior to deblocking $\text{recPicture}_L$, the luma location ( xCb, yCb ), the luma coding block size log2CbSize, the variable edgeType set equal to EDGE_VER, and the array verEdgeFlags as inputs, and an (nCbS)x(nCbS) array verBs as output.

7. The vertical edge filtering process for a coding unit as specified in subclause 8.7.2.5.1 is invoked with the reconstructed picture sample arrays prior to deblocking $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$, the luma location ( xCb, yCb ), the luma coding block size log2CbSize, and the array verBs as inputs, and the modified reconstructed picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$ as outputs.

When slice_deblocking_filter_disabled_flag of the current slice is equal to 0, for each coding unit with luma coding block size log2CbSize and location of top-left sample of the luma coding block ( xCb, yCb ), the horizontal edges are filtered by the following ordered steps:

1. The luma coding block size nCbS is set equal to 1 << log2CbSize.

2. The variable filterTopCbEdgeFlag is derived as follows:

  – If one or more of the following conditions are true, the variable filterTopCbEdgeFlag is set equal to 0:

    – The top boundary of the current luma coding block is the top boundary of the picture.

    – The top boundary of the current luma coding block is the top boundary of the tile and loop_filter_across_tiles_enabled_flag is equal to 0.

    – The top boundary of the current luma coding block is the top boundary of the slice and slice_loop_filter_across_slices_enabled_flag is equal to 0.

  – Otherwise, the variable filterTopCbEdgeFlag is set equal to 1.

3. All elements of the two-dimensional (nCbS)x(nCbS) array horEdgeFlags are initialized to zero.

4. The derivation process of transform block boundary specified in subclause 8.7.2.2 is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ) set equal to ( 0, 0 ), the transform block size log2TrafoSize set equal to log2CbSize, the variable trafoDepth set equal to 0, the variable filterTopCbEdgeFlag, the array horEdgeFlags, and the variable edgeType set equal to EDGE_HOR as inputs, and the modified array horEdgeFlags as output.

5. The derivation process of prediction block boundary specified in subclause 8.7.2.3 is invoked with the luma coding block size log2CbSize, the prediction partition mode PartMode, the array horEdgeFlags, and the variable edgeType set equal to EDGE_HOR as inputs, and the modified array horEdgeFlags as output.

6. The derivation process of the boundary filtering strength specified in subclause 8.7.2.4 is invoked with the reconstructed luma picture sample array prior to deblocking $\text{recPicture}_L$, the luma location ( xCb, yCb ), the luma coding block size log2CbSize, the variable edgeType set equal to EDGE_HOR, and the array horEdgeFlags as inputs, and an (nCbS)x(nCbS) array horBs as output.

7. The horizontal edge filtering process for a coding unit as specified in subclause 8.7.2.5.2 is invoked with the modified reconstructed picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$, the luma location ( xCb, yCb ), the luma coding block size log2CbSize and the array horBs as inputs, and the modified reconstructed picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$ as outputs.

### 8.7.2.2 Derivation process of transform block boundary

Inputs to this process are:

- a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,
- a luma location ( xB0, yB0 ) specifying the top-left sample of the current luma block relative to the top-left sample of the current luma coding block,
- a variable log2TrafoSize specifying the size of the current block,
- a variable trafoDepth,
- a variable filterEdgeFlag,
- a two-dimensional (nCbS)x(nCbS) array edgeFlags,
- a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered.

Output of this process is the modified two-dimensional (nCbS)x(nCbS) array edgeFlags.

Depending on the value of split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ], the following applies:

- If split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 1, the following ordered steps apply:
  1. The variables xB1 and yB1 are derived as follows:
     - The variable xB1 is set equal to xB0 + ( 1 << ( log2TrafoSize − 1 ) ).
     - The variable yB1 is set equal to yB0 + ( 1 << ( log2TrafoSize − 1 ) ).
  2. The derivation process of transform block boundary as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable filterEdgeFlag, the array edgeFlags, and the variable edgeType as inputs, and the output is the modified version of array edgeFlags.
  3. The derivation process of transform block boundary as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB0 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable filterEdgeFlag, the array edgeFlags, and the variable edgeType as inputs, and the output is the modified version of array edgeFlags.
  4. The derivation process of transform block boundary as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB0, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable filterEdgeFlag, the array edgeFlags, and the variable edgeType as inputs, and the output is the modified version of array edgeFlags.
  5. The derivation process of transform block boundary as specified in this subclause is invoked with the luma location ( xCb, yCb ), the luma location ( xB1, yB1 ), the variable log2TrafoSize set equal to log2TrafoSize − 1, the variable trafoDepth set equal to trafoDepth + 1, the variable filterEdgeFlag, the array edgeFlags, and the variable edgeType as inputs, and the output is the modified version of array edgeFlags.
- Otherwise (split_transform_flag[ xCb + xB0 ][ yCb + yB0 ][ trafoDepth ] is equal to 0), the following applies:
  - If edgeType is equal to EDGE_VER, the value of edgeFlags[ xB0 ][ yB0 + k ] for k = 0..( 1 << log2TrafoSize ) − 1 is derived as follows:
    - If xB0 is equal to 0, edgeFlags[ xB0 ][ yB0 + k ] is set equal to filterEdgeFlag.
    - Otherwise, edgeFlags[ xB0 ][ yB0 + k ] is set equal to 1.
  - Otherwise (edgeType is equal to EDGE_HOR), the value of edgeFlags[ xB0 + k ][ yB0 ] for k = 0..( 1 << log2TrafoSize ) − 1 is derived as follows:
    - If yB0 is equal to 0, edgeFlags[ xB0 + k ][ yB0 ] is set equal to filterEdgeFlag.
    - Otherwise, edgeFlags[ xB0 + k ][ yB0 ] is set equal to 1.

### 8.7.2.3 Derivation process of prediction block boundary

Inputs to this process are:

- a variable log2CbSize specifying the luma coding block size,
- a prediction partition mode PartMode,
- a two-dimensional (nCbS)x(nCbS) array edgeFlags,
- a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered.

Output of this process is the modified two-dimensional (nCbS)x(nCbS) array edgeFlags.

Depending on the values of edgeType and PartMode, the following applies for k = 0..( 1 << log2CbSize ) − 1:

– If edgeType is equal to EDGE_VER, the following applies:

  – When PartMode is equal to PART_Nx2N or PART_NxN, edgeFlags[ 1 << ( log2CbSize − 1 ) ][ k ] is set equal to 1.

  – When PartMode is equal to PART_nLx2N, edgeFlags[ 1 << ( log2CbSize − 2 ) ][ k ] is set equal to 1.

  – When PartMode is equal to PART_nRx2N, edgeFlags[ 3 * ( 1 << ( log2CbSize − 2 ) ) ][ k ] is set equal to 1.

– Otherwise (edgeType is equal to EDGE_HOR), the following applies:

  – When PartMode is equal to PART_2NxN or PART_NxN, edgeFlags[ k ][ 1 << ( log2CbSize − 1 ) ] is set equal to 1.

  – When PartMode is equal to PART_2NxnU, edgeFlags[ k ][ 1 << ( log2CbSize − 2 ) ] is set equal to 1.

  – When PartMode is equal to PART_2NxnD, edgeFlags[ k ][ 3 * ( 1 << ( log2CbSize − 2 ) ) ] is set equal to 1.

### 8.7.2.4 Derivation process of boundary filtering strength

Inputs to this process are:

– a luma picture sample array $recPicture_L$,

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current luma coding block,

– a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered,

– a two-dimensional (nCbS)x(nCbS) array edgeFlags.

Output of this process is a two-dimensional (nCbS)x(nCbS) array bS specifying the boundary filtering strength.

The variables $xD_i$, $yD_j$, xN, and yN are derived as follows:

– If edgeType is equal to EDGE_VER, $xD_i$ is set equal to ( i << 3 ), $yD_j$ is set equal to ( j << 2 ), xN is set equal to ( 1 << ( log2CbSize − 3 ) ) − 1, and yN is set equal to ( 1 << ( log2CbSize − 2 ) ) − 1.

– Otherwise (edgeType is equal to EDGE_HOR), $xD_i$ is set equal to ( i << 2 ), $yD_j$ is set equal to ( j << 3 ), xN is set equal to ( 1 << ( log2CbSize − 2 ) ) − 1, and yN is set equal to ( 1 << ( log2CbSize − 3 ) ) − 1.

For $xD_i$ with i = 0..xN and $yD_j$ with j = 0..yN, the following applies:

  – If edgeFlags[ $xD_i$ ][ $yD_j$ ] is equal to 0, the variable bS[ $xD_i$ ][ $yD_j$ ] is set equal to 0.

  – Otherwise (edgeFlags[ $xD_i$ ][ $yD_j$ ] is equal to 1), the following applies:

    – The sample values $p_0$ and $q_0$ are derived as follows:

      – If edgeType is equal to EDGE_VER, $p_0$ is set equal to $recPicture_L$[ xCb + $xD_i$ − 1 ][ yCb + $yD_j$ ] and $q_0$ is set equal to $recPicture_L$[ xCb + $xD_i$ ][ yCb + $yD_j$ ].

      – Otherwise (edgeType is equal to EDGE_HOR), $p_0$ is set equal to $recPicture_L$[ xCb + $xD_i$ ][ yCb + $yD_j$ − 1 ] and $q_0$ is set equal to $recPicture_L$[ xCb + $xD_i$ ][ yCb + $yD_j$ ].

    – The variable bS[ $xD_i$ ][ $yD_j$ ] is derived as follows:

      – If the sample $p_0$ or $q_0$ is in the luma coding block of a coding unit coded with intra prediction mode, bS[ $xD_i$ ][ $yD_j$ ] is set equal to 2.

      – Otherwise, if the block edge is also a transform block edge and the sample $p_0$ or $q_0$ is in a luma transform block which contains one or more non-zero transform coefficient levels, bS[ $xD_i$ ][ $yD_j$ ] is set equal to 1.

      – Otherwise, if one or more of the following conditions are true, bS[ $xD_i$ ][ $yD_j$ ] is set equal to 1:

        – For the prediction of the luma prediction block containing the sample $p_0$ different reference pictures or a different number of motion vectors are used than for the prediction of the luma prediction block containing the sample $q_0$.

NOTE 1 – The determination of whether the reference pictures used for the two luma prediction blocks are the same or different is based only on which pictures are referenced, without regard to whether a prediction is formed using an index into reference picture list 0 or an index into reference picture list 1, and also without regard to whether the index position within a reference picture list is different.

NOTE 2 – The number of motion vectors that are used for the prediction of a luma prediction block with top-left luma sample covering ( xPb, yPb ), is equal to PredFlagL0[ xPb ][ yPb ] + PredFlagL1[ xPb ][ yPb ].

– One motion vector is used to predict the luma prediction block containing the sample $p_0$ and one motion vector is used to predict the luma prediction block containing the sample $q_0$, and the absolute difference between the horizontal or vertical component of the motion vectors used is greater than or equal to 4 in units of quarter luma samples.

– Two motion vectors and two different reference pictures are used to predict the luma prediction block containing the sample $p_0$, two motion vectors for the same two reference pictures are used to predict the luma prediction block containing the sample $q_0$, and the absolute difference between the horizontal or vertical component of the two motion vectors used in the prediction of the two luma prediction blocks for the same reference picture is greater than or equal to 4 in units of quarter luma samples.

– Two motion vectors for the same reference picture are used to predict the luma prediction block containing the sample $p_0$, two motion vectors for the same reference picture are used to predict the luma prediction block containing the sample $q_0$, and both of the following conditions are true:

  – The absolute difference between the horizontal or vertical component of list 0 motion vectors used in the prediction of the two luma prediction blocks is greater than or equal to 4 in quarter luma samples, or the absolute difference between the horizontal or vertical component of the list 1 motion vectors used in the prediction of the two luma prediction blocks is greater than or equal to 4 in units of quarter luma samples.

  – The absolute difference between the horizontal or vertical component of list 0 motion vector used in the prediction of the luma prediction block containing the sample $p_0$ and the list 1 motion vector used in the prediction of the luma prediction block containing the sample $q_0$ is greater than or equal to 4 in units of quarter luma samples, or the absolute difference between the horizontal or vertical component of the list 1 motion vector used in the prediction of the luma prediction block containing the sample $p_0$ and list 0 motion vector used in the prediction of the luma prediction block containing the sample $q_0$ is greater than or equal to 4 in units of quarter luma samples.

– Otherwise, the variable bS[ $xD_i$ ][ $yD_j$ ] is set equal to 0.

### 8.7.2.5 Edge filtering process

#### 8.7.2.5.1 Vertical edge filtering process

Inputs to this process are:

– the picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$,

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a variable log2CbSize specifying the size of the current luma coding block,

– an array bS specifying the boundary filtering strength.

Outputs of this process are the modified picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$.

The filtering process for edges in the luma coding block of the current coding unit consists of the following ordered steps:

1. The variable nD is set equal to 1 << ( log2CbSize − 3 ).

2. For $xD_k$ equal to k << 3 with k = 0..nD − 1 and $yD_m$ equal to m << 2 with m = 0..nD * 2 − 1, the following applies:

   – When bS[ $xD_k$ ][ $yD_m$ ] is greater than 0, the following ordered steps apply:

a. The decision process for luma block edges as specified in subclause 8.7.2.5.3 is invoked with the luma picture sample array $recPicture_L$, the location of the luma coding block ( xCb, yCb ), the luma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_VER, and the boundary filtering strength bS[ $xD_k$ ][ $yD_m$ ] as inputs, and the decisions dE, dEp, and dEq, and the variables β and $t_C$ as outputs.

b. The filtering process for luma block edges as specified in subclause 8.7.2.5.4 is invoked with the luma picture sample array $recPicture_L$, the location of the luma coding block ( xCb, yCb ), the luma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_VER, the decisions dE, dEp, and dEq, and the variables β and $t_C$ as inputs, and the modified luma picture sample array $recPicture_L$ as output.

The filtering process for edges in the chroma coding blocks of current coding unit consists of the following ordered steps:

1. The variable nD is set equal to 1 << ( log2CbSize − 3 ).
2. For $xD_k$ equal to k << 2 with k = 0..nD − 1 and $yD_m$ equal to m << 2 with m = 0..nD − 1, the following applies:
   – When bS[ $xD_k$ * 2 ][ $yD_m$ * 2 ] is equal to 2 and ( ( ( xCb / 2 + $xD_k$ ) >> 3 ) << 3 ) is equal to xCb / 2 + $xD_k$, the following ordered steps apply:
     a. The filtering process for chroma block edges as specified in subclause 8.7.2.5.5 is invoked with the chroma picture sample array $recPicture_{Cb}$, the location of the chroma coding block ( xCb / 2, yCb / 2 ), the chroma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_VER, and a variable cQpPicOffset set equal to pps_cb_qp_offset as inputs, and the modified chroma picture sample array $recPicture_{Cb}$ as output.
     b. The filtering process for chroma block edges as specified in subclause 8.7.2.5.5 is invoked with the chroma picture sample array $recPicture_{Cr}$, the location of the chroma coding block ( xCb / 2, yCb / 2 ), the chroma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_VER, and a variable cQpPicOffset set equal to pps_cr_qp_offset as inputs, and the modified chroma picture sample array $recPicture_{Cr}$ as output.

### 8.7.2.5.2 Horizontal edge filtering process

Inputs to this process are:

– the picture sample arrays $recPicture_L$, $recPicture_{Cb}$, and $recPicture_{Cr}$,
– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,
– a variable log2CbSize specifying the size of the current luma coding block,
– an array bS specifying the boundary filtering strength.

Outputs of this process are the modified picture sample arrays $recPicture_L$, $recPicture_{Cb}$, and $recPicture_{Cr}$.

The filtering process for edges in the luma coding block of the current coding unit consists of the following ordered steps:

1. The variable nD is set equal to 1 << ( log2CbSize − 3 ).
2. For $yD_m$ equal to m << 3 with m = 0..nD − 1, and $xD_k$ equal to k << 2 with k = 0..nD * 2 − 1, the following applies:
   – When bS[ $xD_k$ ][ $yD_m$ ] is greater than 0, the following ordered steps apply:
     a. The decision process for luma block edges as specified in subclause 8.7.2.5.3 is invoked with the luma picture sample array $recPicture_L$, the location of the luma coding block ( xCb, yCb ), the luma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_HOR, and the boundary filtering strength bS[ $xD_k$ ][ $yD_m$ ] as inputs, and the decisions dE, dEp, and dEq, and the variables β and $t_C$ as outputs.
     b. The filtering process for luma block edges as specified in subclause 8.7.2.5.4 is invoked with the luma picture sample array $recPicture_L$, the location of the luma coding block ( xCb, yCb ), the luma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_HOR, the decisions dEp, dEp, and dEq, and the variables β and $t_C$ as inputs, and the modified luma picture sample array $recPicture_L$ as output.

The filtering process for edges in the chroma coding blocks of current coding unit consists of the following ordered steps:

1. The variable nD is set equal to $1 << ( \text{log2CbSize} - 3 )$.
2. For $yD_m$ equal to $m << 2$ with $m = 0..nD - 1$ and $xD_k$ equal to $k << 2$ with $k = 0..nD - 1$, the following applies:
   - When $bS[ xD_k * 2 ][ yD_m * 2 ]$ is equal to 2 and $( ( ( yCb / 2 + yD_m ) >> 3 ) << 3 )$ is equal to $yCb / 2 + yD_m$, the following ordered steps apply:
     a. The filtering process for chroma block edges as specified in subclause 8.7.2.5.5 is invoked with the chroma picture sample array $\text{recPicture}_{Cb}$, the location of the chroma coding block ( xCb / 2, yCb / 2 ), the chroma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_HOR, and a variable cQpPicOffset set equal to pps_cb_qp_offset as inputs, and the modified chroma picture sample array $\text{recPicture}_{Cb}$ as output.
     b. The filtering process for chroma block edges as specified in subclause 8.7.2.5.5 is invoked with the chroma picture sample array $\text{recPicture}_{Cr}$, the location of the chroma coding block ( xCb / 2, yCb / 2 ), the chroma location of the block ( $xD_k$, $yD_m$ ), a variable edgeType set equal to EDGE_HOR, and a variable cQpPicOffset set equal to pps_cr_qp_offset as inputs, and the modified chroma picture sample array $\text{recPicture}_{Cr}$ as output.

#### 8.7.2.5.3 Decision process for luma block edges

Inputs to this process are:

– a luma picture sample array $\text{recPicture}_L$,

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) specifying the top-left sample of the current luma block relative to the top-left sample of the current luma coding block,

– a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered,

– a variable bS specifying the boundary filtering strength.

Outputs of this process are:

– the variables dE, dEp, and dEq containing decisions,

– the variables $\beta$ and $t_C$.

If edgeType is equal to EDGE_VER, the sample values $p_{i,k}$ and $q_{i,k}$ with i = 0..3 and k = 0 and 3 are derived as follows:

$$q_{i,k} = \text{recPicture}_L[ xCb + xBl + i ][ yCb + yBl + k ] \quad (8\text{-}284)$$

$$p_{i,k} = \text{recPicture}_L[ xCb + xBl - i - 1 ][ yCb + yBl + k ] \quad (8\text{-}285)$$

Otherwise (edgeType is equal to EDGE_HOR), the sample values $p_{i,k}$ and $q_{i,k}$ with i = 0..3 and k = 0 and 3 are derived as follows:

$$q_{i,k} = \text{recPicture}_L[ xCb + xBl + k ][ yCb + yBl + i ] \quad (8\text{-}286)$$

$$p_{i,k} = \text{recPicture}_L[ xCb + xBl + k ][ yCb + yBl - i - 1 ] \quad (8\text{-}287)$$

The variables $Qp_Q$ and $Qp_P$ are set equal to the $Qp_Y$ values of the coding units which include the coding blocks containing the sample $q_{0,0}$ and $p_{0,0}$, respectively.

A variable $qP_L$ is derived as follows:

$$qP_L = ( ( Qp_Q + Qp_P + 1 ) >> 1 ) \quad (8\text{-}288)$$

The value of the variable $\beta'$ is determined as specified in Table 8-11 based on the luma quantization parameter Q derived as follows:

$$Q = \text{Clip3}( 0, 51, qP_L + ( \text{slice\_beta\_offset\_div2} << 1 ) ) \quad (8\text{-}289)$$

where slice_beta_offset_div2 is the value of the syntax element slice_beta_offset_div2 for the slice that contains sample $q_{0,0}$.

The variable β is derived as follows:

$\beta = \beta' * ( 1 \ll ( \text{BitDepth}_Y - 8 ) )$ (8-290)

The value of the variable $t_C'$ is determined as specified in Table 8-11 based on the luma quantization parameter Q derived as follows:

$Q = \text{Clip3}( 0, 53, qP_L + 2 * ( bS - 1 ) + ( \text{slice\_tc\_offset\_div2} \ll 1 ) )$ (8-291)

where slice_tc_offset_div2 is the value of the syntax element slice_tc_offset_div2 for the slice that contains sample $q_{0,0}$.

The variable $t_C$ is derived as follows:

$t_C = t_C' * ( 1 \ll ( \text{BitDepth}_Y - 8 ) )$ (8-292)

Depending on the value of edgeType, the following applies:

– If edgeType is equal to EDGE_VER, the following ordered steps apply:

1. The variables dpq0, dpq3, dp, dq, and d are derived as follows:

   $dp0 = \text{Abs}( p_{2,0} - 2 * p_{1,0} + p_{0,0} )$ (8-293)

   $dp3 = \text{Abs}( p_{2,3} - 2 * p_{1,3} + p_{0,3} )$ (8-294)

   $dq0 = \text{Abs}( q_{2,0} - 2 * q_{1,0} + q_{0,0} )$ (8-295)

   $dq3 = \text{Abs}( q_{2,3} - 2 * q_{1,3} + q_{0,3} )$ (8-296)

   $dpq0 = dp0 + dq0$ (8-297)

   $dpq3 = dp3 + dq3$ (8-298)

   $dp = dp0 + dp3$ (8-299)

   $dq = dq0 + dq3$ (8-300)

   $d = dpq0 + dpq3$ (8-301)

2. The variables dE, dEp, and dEq are set equal to 0.

3. When d is less than β, the following ordered steps apply:

   a. The variable dpq is set equal to 2 * dpq0.

   b. For the sample location ( xCb + xBl, yCb + yBl ), the decision process for a luma sample as specified in subclause 8.7.2.5.6 is invoked with sample values $p_{i,0}$, $q_{i,0}$ with i = 0..3, the variables dpq, β, and $t_C$ as inputs, and the output is assigned to the decision dSam0.

   c. The variable dpq is set equal to 2 * dpq3.

   d. For the sample location ( xCb + xBl, yCb + yBl + 3 ), the decision process for a luma sample as specified in subclause 8.7.2.5.6 is invoked with sample values $p_{i,3}$, $q_{i,3}$ with i = 0..3, the variables dpq, β, and $t_C$ as inputs, and the output is assigned to the decision dSam3.

   e. The variable dE is set equal to 1.

   f. When dSam0 is equal to 1 and dSam3 is equal to 1, the variable dE is set equal to 2.

   g. When dp is less than ( β + ( β >> 1 ) ) >> 3, the variable dEp is set equal to 1.

   h. When dq is less than ( β + ( β >> 1 ) ) >> 3, the variable dEq is set equal to 1.

– Otherwise (edgeType is equal to EDGE_HOR), the following ordered steps apply:

1. The variables dpq0, dpq3, dp, dq, and d are derived as follows:

   $dp0 = \text{Abs}( p_{2,0} - 2 * p_{1,0} + p_{0,0} )$ (8-302)

   $dp3 = \text{Abs}( p_{2,3} - 2 * p_{1,3} + p_{0,3} )$ (8-303)

   $dq0 = \text{Abs}( q_{2,0} - 2 * q_{1,0} + q_{0,0} )$ (8-304)

   $dq3 = \text{Abs}( q_{2,3} - 2 * q_{1,3} + q_{0,3} )$ (8-305)

   $dpq0 = dp0 + dq0$ (8-306)

   $dpq3 = dp3 + dq3$ (8-307)

$$dp = dp0 + dp3 \tag{8-308}$$

$$dq = dq0 + dq3 \tag{8-309}$$

$$d = dpq0 + dpq3 \tag{8-310}$$

2. The variables dE, dEp, and dEq are set equal to 0.
3. When d is less than β, the following ordered steps apply:
   a. The variable dpq is set equal to 2 * dpq0.
   b. For the sample location ( xCb + xBl, yCb + yBl ), the decision process for a luma sample as specified in subclause 8.7.2.5.6 is invoked with sample values $p_{0,0}$, $p_{3,0}$, $q_{0,0}$, and $q_{3,0}$, the variables dpq, β, and $t_C$ as inputs, and the output is assigned to the decision dSam0.
   c. The variable dpq is set equal to 2 * dpq3.
   d. For the sample location ( xCb + xBl + 3, yCb + yBl ), the decision process for a luma sample as specified in subclause 8.7.2.5.6 is invoked with sample values $p_{0,3}$, $p_{3,3}$, $q_{0,3}$, and $q_{3,3}$, the variables dpq, β, and $t_C$ as inputs, and the output is assigned to the decision dSam3.
   e. The variable dE is set equal to 1.
   f. When dSam0 is equal to 1 and dSam3 is equal to 1, the variable dE is set equal to 2.
   g. When dp is less than ( β + ( β >> 1 ) ) >> 3, the variable dEp is set equal to 1.
   h. When dq is less than ( β + ( β >> 1 ) ) >> 3, the variable dEq is set equal to 1.

**Table 8-11 – Derivation of threshold variables β′ and $t_C$′ from input Q**

| **Q** | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **β′** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 7 | 8 |
| **$t_C$′** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| **Q** | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 |
| **β′** | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 |
| **$t_C$′** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 3 | 4 | 4 | 4 |
| **Q** | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | | | |
| **β′** | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 | 58 | 60 | 62 | 64 | - | - | | | |
| **$t_C$′** | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 16 | 18 | 20 | 22 | 24 | | | |

#### 8.7.2.5.4 Filtering process for luma block edges

Inputs to this process are:

– a luma picture sample array $recPicture_L$,

– a luma location ( xCb, yCb ) specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture,

– a luma location ( xBl, yBl ) specifying the top-left sample of the current luma block relative to the top-left sample of the current luma coding block,

– a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered,

– the variables dE, dEp, and dEq containing decisions,

– the variables β and $t_C$.

Output of this process is the modified luma picture sample array $recPicture_L$.

Depending on the value of edgeType, the following applies:

– If edgeType is equal to EDGE_VER, the following ordered steps apply:

  1. The sample values $p_{i,k}$ and $q_{i,k}$ with i = 0..3 and k = 0..3 are derived as follows:

$q_{i,k}$ = recPicture$_L$[ xCb + xBl + i ][ yCb + yBl + k ] (8-311)

$p_{i,k}$ = recPicture$_L$[ xCb + xBl − i − 1 ][ yCb + yBl + k ] (8-312)

2. When dE is not equal to 0, for each sample location ( xCb + xBl, yCb + yBl + k ), k = 0..3, the following ordered steps apply:

   a. The filtering process for a luma sample as specified in subclause 8.7.2.5.7 is invoked with the sample values $p_{i,k}$, $q_{i,k}$ with i = 0..3, the locations ( $xP_i$, $yP_i$ ) set equal to ( xCb + xBl − i − 1, yCb + yBl + k ) and ( $xQ_i$, $yQ_i$ ) set equal to ( xCb + xBl + i, yCb + yBl + k ) with i = 0..2, the decision dE, the variables dEp and dEq, and the variable $t_C$ as inputs, and the number of filtered samples nDp and nDq from each side of the block boundary, and the filtered sample values $p_i$' and $q_j$' as outputs.

   b. When nDp is greater than 0, the filtered sample values $p_i$' with i = 0..nDp − 1 replace the corresponding samples inside the sample array recPicture$_L$ as follows:

      recPicture$_L$[ xCb + xBl − i − 1 ][ yCb + yBl + k ] = $p_i$' (8-313)

   c. When nDq is greater than 0, the filtered sample values $q_j$' with j = 0..nDq − 1 replace the corresponding samples inside the sample array recPicture$_L$ as follows:

      recPicture$_L$[ xCb + xBl + j ][ yCb + yBl + k ] = $q_j$' (8-314)

– Otherwise (edgeType is equal to EDGE_HOR), the following ordered steps apply:

1. The sample values $p_{i,k}$ and $q_{i,k}$ with i = 0..3 and k = 0..3 are derived as follows:

   $q_{i,k}$ = recPicture$_L$[ xCb + xBl + k ][ yCb + yBl + i ] (8-315)

   $p_{i,k}$ = recPicture$_L$[ xCb + xBl + k ][ yCb + yBl − i − 1 ] (8-316)

2. When dE is not equal to 0, for each sample location ( xCb + xBl + k, yCb + yBl ), k = 0..3, the following ordered steps apply:

   a. The filtering process for a luma sample as specified in subclause 8.7.2.5.7 is invoked with the sample values $p_{i,k}$, $q_{i,k}$ with i = 0..3, the locations ( $xP_i$, $yP_i$ ) set equal to ( xCb + xBl + k, yCb + yBl − i − 1 ) and ( $xQ_i$, $yQ_i$ ) set equal to ( xCb + xBl + k, yCb + yBl + i ) with i = 0..2, the decision dE, the variables dEp and dEq, and the variable $t_C$ as inputs, and the number of filtered samples nDp and nDq from each side of the block boundary and the filtered sample values $p_i$' and $q_j$' as outputs.

   b. When nDp is greater than 0, the filtered sample values $p_i$' with i = 0..nDp − 1 replace the corresponding samples inside the sample array recPicture$_L$ as follows:

      recPicture$_L$[ xCb + xBl + k ][ yCb + yBl − i − 1 ] = $p_i$' (8-317)

   c. When nDq is greater than 0, the filtered sample values $q_j$' with j = 0..nDq − 1 replace the corresponding samples inside the sample array recPicture$_L$ as follows:

      recPicture$_L$[ xCb + xBl + k ][ yCb + yBl + j ] = $q_j$' (8-318)

### 8.7.2.5.5 Filtering process for chroma block edges

Inputs to this process are:

– a chroma picture sample array s′,

– a chroma location ( xCb, yCb ) specifying the top-left sample of the current chroma coding block relative to the top-left chroma sample of the current picture,

– a chroma location ( xBl, yBl ) specifying the top-left sample of the current chroma block relative to the top-left sample of the current chroma coding block,

– a variable edgeType specifying whether a vertical (EDGE_VER) or a horizontal (EDGE_HOR) edge is filtered,

– a variable cQpPicOffset specifying the picture-level chroma quantization parameter offset.

Output of this process is the modified chroma picture sample array s′.

If edgeType is equal to EDGE_VER, the values $p_i$ and $q_i$ with i = 0..1 and k = 0..3 are derived as follows:

$q_{i,k}$ = s′[ xCb + xBl + i ][ yCb + yBl + k ] (8-319)

$p_{i,k}$ = s′[ xCb + xBl − i − 1 ][ yCb + yBl + k ] (8-320)

Otherwise (edgeType is equal to EDGE_HOR), the sample values $p_i$ and $q_i$ with i = 0..1 and k = 0..3 are derived as follows:

$$q_{i,k} = s'[\ xCb + xBl + k\ ][\ yCb + yBl + i\ ] \quad (8\text{-}321)$$

$$p_{i,k} = s'[\ xCb + xBl + k\ ][\ yCb + yBl - i - 1\ ] \quad (8\text{-}322)$$

The variables $Qp_Q$ and $Qp_P$ are set equal to the $Qp_Y$ values of the coding units which include the coding blocks containing the sample $q_{0,0}$ and $p_{0,0}$, respectively.

The variable $Qp_C$ is determined as specified in Table 8-9 based on the index qPi derived as follows:

$$qPi = (\ (\ Qp_Q + Qp_P + 1\ ) \gg 1\ ) + cQpPicOffset \quad (8\text{-}323)$$

NOTE – The variable cQpPicOffset provides an adjustment for the value of pps_cb_qp_offset or pps_cr_qp_offset, according to whether the filtered chroma component is the Cb or Cr component. However, to avoid the need to vary the amount of the adjustment within the picture, the filtering process does not include an adjustment for the value of slice_cb_qp_offset or slice_cr_qp_offset.

The value of the variable $t_C'$ is determined as specified in Table 8-11 based on the chroma quantization parameter Q derived as follows:

$$Q = \text{Clip3}(\ 0, 53, Qp_C + 2 + (\ slice\_tc\_offset\_div2 \ll 1\ )\ ) \quad (8\text{-}324)$$

where slice_tc_offset_div2 is the value of the syntax element slice_tc_offset_div2 for the slice that contains sample $q_{0,0}$.

The variable $t_C$ is derived as follows:

$$t_C = t_C' * (\ 1 \ll (\ BitDepth_C - 8\ )\ ) \quad (8\text{-}325)$$

Depending on the value of edgeType, the following applies:

– If edgeType is equal to EDGE_VER, for each sample location ( xCb + xBl, yCb + yBl + k ), k = 0..3, the following ordered steps apply:

1. The filtering process for a chroma sample as specified in subclause 8.7.2.5.8 is invoked with the sample values $p_{i,k}$, $q_{i,k}$, with i = 0..1, the locations ( xCb + xBl − 1, yCb + yBl + k ) and ( xCb + xBl, yCb + yBl + k ), and the variable $t_C$ as inputs, and the filtered sample values $p_0'$ and $q_0'$ as outputs.

2. The filtered sample values $p_0'$ and $q_0'$ replace the corresponding samples inside the sample array s′ as follows:

$$s'[\ xCb + xBl\ ][\ yCb + yBl + k\ ] = q_0' \quad (8\text{-}326)$$

$$s'[\ xCb + xBl - 1\ ][\ yCb + yBl + k\ ] = p_0' \quad (8\text{-}327)$$

– Otherwise (edgeType is equal to EDGE_HOR), for each sample location ( xCb + xBl + k, yCb + yBl ), k = 0..3, the following ordered steps apply:

1. The filtering process for a chroma sample as specified in subclause 8.7.2.5.8 is invoked with the sample values $p_{i,k}$, $q_{i,k}$, with i = 0..1, the locations ( xCb + xBl + k, yCb + yBl − 1 ) and ( xCb + xBl + k, yCb + yBl ), and the variable $t_C$ as inputs, and the filtered sample values $p_0'$ and $q_0'$ as outputs.

2. The filtered sample values $p_0'$ and $q_0'$ replace the corresponding samples inside the sample array s′ as follows:

$$s'[\ xCb + xBl + k\ ][\ yCb + yBl\ ] = q_0' \quad (8\text{-}328)$$

$$s'[\ xCb + xBl + k\ ][\ yCb + yBl - 1\ ] = p_0' \quad (8\text{-}329)$$

### 8.7.2.5.6 Decision process for a luma sample

Inputs to this process are:

– the sample values $p_0$, $p_3$, $q_0$, and $q_3$,

– the variables dpq, β, and $t_C$.

Output of this process is the variable dSam containing a decision.

The variable dSam is specified as follows:

– If dpq is less than ( β >> 2 ), Abs( $p_3 - p_0$ ) + Abs( $q_0 - q_3$ ) is less than ( β >> 3 ), and Abs( $p_0 - q_0$ ) is less than ( 5 * $t_C$ + 1 ) >> 1, dSam is set equal to 1.

– Otherwise, dSam is set equal to 0.

### 8.7.2.5.7 Filtering process for a luma sample

Inputs to this process are:

– the luma sample values $p_i$ and $q_i$ with i = 0..3,

– the luma locations of $p_i$ and $q_i$, ( $xP_i$, $yP_i$ ) and ( $xQ_i$, $yQ_i$ ) with i = 0..2,

– a variable dE,

– the variables dEp and dEq containing decisions to filter samples p1 and q1 respectively,

– a variable $t_C$.

Outputs of this process are:

– the number of filtered samples nDp and nDq,

– the filtered sample values $p_i'$ and $q_j'$ with i = 0..nDp − 1, j = 0..nDq − 1.

Depending on the value of dE, the following applies:

– If the variable dE is equal to 2, nDp and nDq are both set equal to 3, and the following strong filtering applies:

$$p_0' = \text{Clip3}(\ p_0 - 2 * t_C,\ p_0 + 2 * t_C,\ (\ p_2 + 2 * p_1 + 2 * p_0 + 2 * q_0 + q_1 + 4\ ) >> 3\ ) \quad (8\text{-}330)$$

$$p_1' = \text{Clip3}(\ p_1 - 2 * t_C,\ p_1 + 2 * t_C,\ (\ p_2 + p_1 + p_0 + q_0 + 2\ ) >> 2\ ) \quad (8\text{-}331)$$

$$p_2' = \text{Clip3}(\ p_2 - 2 * t_C,\ p_2 + 2{*}t_C,\ (\ 2 * p_3 + 3 * p_2 + p_1 + p_0 + q_0 + 4\ ) >> 3\ ) \quad (8\text{-}332)$$

$$q_0' = \text{Clip3}(\ q_0 - 2 * t_C,\ q_0 + 2 * t_C,\ (\ p_1 + 2 * p_0 + 2 * q_0 + 2 * q_1 + q_2 + 4\ ) >> 3\ ) \quad (8\text{-}333)$$

$$q_1' = \text{Clip3}(\ q_1 - 2 * t_C,\ q_1 + 2 * t_C,\ (\ p_0 + q_0 + q_1 + q_2 + 2\ ) >> 2\ ) \quad (8\text{-}334)$$

$$q_2' = \text{Clip3}(\ q_2 - 2 * t_C,\ q_2 + 2 * t_C,\ (\ p_0 + q_0 + q_1 + 3 * q_2 + 2 * q_3 + 4\ ) >> 3\ ) \quad (8\text{-}335)$$

– Otherwise, nDp and nDq are set both equal to 0, and the following weak filtering applies:

  – The following applies:

$$\Delta = (\ 9 * (\ q_0 - p_0\ ) - 3 * (\ q_1 - p_1\ ) + 8\ ) >> 4 \quad (8\text{-}336)$$

  – When Abs(Δ) is less than $t_C$ * 10, the following ordered steps apply:

    – The filtered sample values $p_0'$ and $q_0'$ are specified as follows:

$$\Delta = \text{Clip3}(\ -t_C,\ t_C,\ \Delta\ ) \quad (8\text{-}337)$$

$$p_0' = \text{Clip1}_Y(\ p_0 + \Delta\ ) \quad (8\text{-}338)$$

$$q_0' = \text{Clip1}_Y(\ q_0 - \Delta\ ) \quad (8\text{-}339)$$

    – When dEp is equal to 1, the filtered sample value $p_1'$ is specified as follows:

$$\Delta p = \text{Clip3}(\ -(\ t_C >> 1\ ),\ t_C >> 1,\ (\ (\ (\ p_2 + p_0 + 1\ ) >> 1\ ) - p_1 + \Delta\ ) >> 1\ ) \quad (8\text{-}340)$$

$$p_1' = \text{Clip1}_Y(\ p_1 + \Delta p\ ) \quad (8\text{-}341)$$

    – When dEq is equal to 1, the filtered sample value $q_1'$ is specified as follows:

$$\Delta q = \text{Clip3}(\ -(\ t_C >> 1\ ),\ t_C >> 1,\ (\ (\ (\ q_2 + q_0 + 1\ ) >> 1\ ) - q_1 - \Delta\ ) >> 1\ ) \quad (8\text{-}342)$$

$$q_1' = \text{Clip1}_Y(\ q_1 + \Delta q\ ) \quad (8\text{-}343)$$

    – nDp is set equal to dEp + 1 and nDq is set equal to dEq + 1.

When nDp is greater than 0 and one or more of the following conditions are true, nDp is set equal to 0:

– pcm_loop_filter_disabled_flag is equal to 1 and pcm_flag[ $xP_0$ ][ $yP_0$ ] is equal to 1.

– cu_transquant_bypass_flag of the coding unit that includes the coding block containing the sample $p_0$ is equal to 1.

When nDq is greater than 0 and one or more of the following conditions are true, nDq is set equal to 0:

– pcm_loop_filter_disabled_flag is equal to 1 and pcm_flag[ $xQ_0$ ][ $yQ_0$ ] is equal to 1.

- cu_transquant_bypass_flag of the coding unit that includes the coding block containing the sample $q_0$ is equal to 1.

#### 8.7.2.5.8 Filtering process for a chroma sample

Inputs to this process are:

- the chroma sample values $p_i$ and $q_i$ with i = 0..1,
- the chroma locations of $p_0$ and $q_0$, ( $xP_0$, $yP_0$ ) and ( $xQ_0$, $yQ_0$ ),
- a variable $t_C$.

Outputs of this process are the filtered sample values $p_0'$ and $q_0'$.

The filtered sample values $p_0'$ and $q_0'$ are derived as follows:

$$\Delta = \text{Clip3}( -t_C, t_C, ( ( ( ( q_0 - p_0 ) \ll 2 ) + p_1 - q_1 + 4 ) \gg 3 ) ) \quad (8\text{-}344)$$

$$p_0' = \text{Clip1}_C( p_0 + \Delta ) \quad (8\text{-}345)$$

$$q_0' = \text{Clip1}_C( q_0 - \Delta ) \quad (8\text{-}346)$$

When one or more of the following conditions are true, the filtered sample value, $p_0'$ is substituted by the corresponding input sample value $p_0$:

- pcm_loop_filter_disabled_flag is equal to 1 and pcm_flag[ 2 * $xP_0$ ][ 2 * $yP_0$ ] is equal to 1.
- cu_transquant_bypass_flag of the coding unit that includes the coding block containing the sample $p_0$ is equal to 1.

When one or more of the following conditions are true, the filtered sample value, $q_0'$ is substituted by the corresponding input sample value $q_0$:

- pcm_loop_filter_disabled_flag is equal to 1 and pcm_flag[ 2 * $xQ_0$ ][ 2 * $yQ_0$ ] is equal to 1.
- cu_transquant_bypass_flag of the coding unit that includes the coding block containing the sample $q_0$ is equal to 1.

### 8.7.3 Sample adaptive offset process

#### 8.7.3.1 General

Inputs to this process are the reconstructed picture sample arrays prior to sample adaptive offset $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$.

Outputs of this process are the modified reconstructed picture sample arrays after sample adaptive offset $\text{saoPicture}_L$, $\text{saoPicture}_{Cb}$, and $\text{saoPicture}_{Cr}$.

This process is performed on a coding tree block basis after the completion of the deblocking filter process for the decoded picture.

The sample values in the modified reconstructed picture sample arrays $\text{saoPicture}_L$, $\text{saoPicture}_{Cb}$, and $\text{saoPicture}_{Cr}$ are initially set equal to the sample values in the reconstructed picture sample arrays $\text{recPicture}_L$, $\text{recPicture}_{Cb}$, and $\text{recPicture}_{Cr}$.

For every coding tree unit with coding tree block location ( rx, ry ), where rx = 0..PicWidthInCtbsY − 1 and ry = 0..PicHeightInCtbsY − 1, the following applies:

- When slice_sao_luma_flag of the current slice is equal to 1, the coding tree block modification process as specified in subclause 8.7.3.2 is invoked with recPicture set equal to $\text{recPicture}_L$, cIdx set equal to 0, ( rx, ry ), and nCtbS set equal to CtbSizeY as inputs, and the modified luma picture sample array $\text{saoPicture}_L$ as output.
- When slice_sao_chroma_flag of the current slice is equal to 1, the coding tree block modification process as specified in subclause 8.7.3.2 is invoked with recPicture set equal to $\text{recPicture}_{Cb}$, cIdx set equal to 1, ( rx, ry ), and nCtbS set equal to ( 1 << ( CtbLog2SizeY − 1 ) ) as inputs, and the modified chroma picture sample array $\text{saoPicture}_{Cb}$ as output.
- When slice_sao_chroma_flag of the current slice is equal to 1, the coding tree block modification process as specified in subclause 8.7.3.2 is invoked with recPicture set equal to $\text{recPicture}_{Cr}$, cIdx set equal to 2, ( rx, ry ), and nCtbS set equal to ( 1 << ( CtbLog2SizeY − 1 ) ) as inputs, and the modified chroma picture sample array $\text{saoPicture}_{Cr}$ as output.

### 8.7.3.2 Coding tree block modification process

Inputs to this process are:

- the picture sample array recPicture for the colour component cIdx,
- a variable cIdx specifying the colour component index,
- a pair of variables ( rx, ry ) specifying the coding tree block location,
- the coding tree block size nCtbS.

Output of this process is a modified picture sample array saoPicture for the colour component cIdx.

The variable bitDepth is derived as follows:

- If cIdx is equal to 0, bitDepth is set equal to $\text{BitDepth}_Y$.
- Otherwise, bitDepth is set equal to $\text{BitDepth}_C$.

The location ( xCtb, yCtb ), specifying the top-left sample of the current coding tree block for the colour component cIdx relative to the top-left sample of the current picture component cIdx, is derived as follows:

$$( xCtb, yCtb ) = ( rx * nCtbS, ry * nCtbS ) \quad (8\text{-}347)$$

The sample locations inside the current coding tree block are derived as follows:

$$( xS_i, yS_j ) = ( xCtb + i, yCtb + j ) \quad (8\text{-}348)$$

$$( xY_i, yY_j ) = ( cIdx == 0 ) \; ? \; ( xS_i, yS_j ) : ( xS_i << 1, yS_j << 1 ) \quad (8\text{-}349)$$

For all sample locations ( $xS_i$, $yS_j$ ) and ( $xY_i$, $yY_j$ ) with i = 0..nCtbS − 1 and j = 0..nCtbS − 1, depending on the values of pcm_loop_filter_disabled_flag, pcm_flag[ $xY_i$ ][ $yY_j$ ], and cu_transquant_bypass_flag of the coding unit which includes the coding block covering recPicture[ $xS_i$ ][ $yS_j$ ], the following applies:

- If one or more of the following conditions are true, saoPicture[ $xS_i$ ][ $yS_j$ ] is not modified:
  - pcm_loop_filter_disabled_flag and pcm_flag[ $xY_i$ ][ $yY_j$ ] are both equal to 1.
  - cu_transquant_bypass_flag is equal to 1.
  - SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 0.
- Otherwise, if SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 2, the following ordered steps apply:
  1. The values of hPos[ k ] and vPos[ k ] for k = 0..1 are specified in Table 8-12 based on SaoEoClass[ cIdx ][ rx ][ ry ].
  2. The variable edgeIdx is derived as follows:
     - The modified sample locations ( $xS_{ik}'$, $yS_{jk}'$ ) and ( $xY_{ik}'$, $yY_{jk}'$ ) are derived as follows:

       $$( xS_{ik}', yS_{jk}' ) = ( xS_i + hPos[ k ], yS_j + vPos[ k ] ) \quad (8\text{-}350)$$

       $$( xY_{ik}', yY_{jk}' ) = ( cIdx == 0 ) \; ? \; ( xS_{ik}', yS_{jk}' ) : ( xS_{ik}' << 1, yS_{jk}' << 1 ) \quad (8\text{-}351)$$

     - If one or more of the following conditions for all sample locations ( $xS_{ik}'$, $yS_{jk}'$ ) and ( $xY_{ik}'$, $yY_{jk}'$ ) with k = 0..1 are true, edgeIdx is set equal to 0:
       - The sample at location ( $xS_{ik}'$, $yS_{jk}'$ ) is outside the picture boundaries.
       - The sample at location ( $xS_{ik}'$, $yS_{jk}'$ ) belongs to a different slice and one of the following two conditions is true:
         - MinTbAddrZs[ $xY_{ik}'$ >> Log2MinTrafoSize ][ $yY_{jk}'$ >> Log2MinTrafoSize ] is less than MinTbAddrZs[ $xY_i$ >> Log2MinTrafoSize ][ $yY_j$ >> Log2MinTrafoSize ] and slice_loop_filter_across_slices_enabled_flag in the slice which the sample recPicture[ $xS_i$ ][ $yS_j$ ] belongs to is equal to 0.
         - MinTbAddrZs[ $xY_i$ >> Log2MinTrafoSize ][ $yY_j$ >> Log2MinTrafoSize ] is less than MinTbAddrZs[ $xY_{ik}'$ >> Log2MinTrafoSize ][ $yY_{jk}'$ >> Log2MinTrafoSize ] and slice_loop_filter_across_slices_enabled_flag in the slice which the sample recPicture[ $xS_{ik}'$ ][ $yS_{jk}'$ ] belongs to is equal to 0.

    – loop_filter_across_tiles_enabled_flag is equal to 0 and the sample at location ( $xS_{ik}'$, $yS_{jk}'$ ) belongs to a different tile.

  – Otherwise, edgeIdx is derived as follows:

    – The following applies:

$$\begin{aligned}\text{edgeIdx} = 2 + \text{Sign}(\ &\text{recPicture}[\ xS_i\ ][\ yS_j\ ] - \text{recPicture}[\ xS_i + \text{hPos}[\ 0\ ]\ ][\ yS_j + \text{vPos}[\ 0\ ]\ ]\ ) + \\ &\text{Sign}(\ \text{recPicture}[\ xS_i\ ][\ yS_j\ ] - \text{recPicture}[\ xS_i + \text{hPos}[\ 1\ ]\ ][\ yS_j + \text{vPos}[\ 1\ ]\ ]\ )\end{aligned} \qquad (8\text{-}352)$$

    – When edgeIdx is equal to 0, 1, or 2, edgeIdx is modified as follows:

$$\text{edgeIdx} = (\ \text{edgeIdx}\ ==\ 2\ )\ ?\ 0 : (\ \text{edgeIdx} + 1\ ) \qquad (8\text{-}353)$$

3. The modified picture sample array saoPicture[ $xS_i$ ][ $yS_j$ ] is derived as follows:

$$\begin{aligned}\text{saoPicture}[\ xS_i\ ][\ yS_j\ ] = \text{Clip3}(\ 0, (\ 1\ <<\ \text{bitDepth}\ ) - 1, &\text{recPicture}[\ xS_i\ ][\ yS_j\ ] + \\ &\text{SaoOffsetVal}[\ \text{cIdx}\ ][\ \text{rx}\ ][\ \text{ry}\ ][\ \text{edgeIdx}\ ]\ )\end{aligned} \qquad (8\text{-}354)$$

– Otherwise (SaoTypeIdx[ cIdx ][ rx ][ ry ] is equal to 1), the following ordered steps apply:

1. The variable bandShift is set equal to bitDepth − 5.

2. The variable saoLeftClass is set equal to sao_band_position[ cIdx ][ rx ][ ry ].

3. The list bandTable is defined with 32 elements and all elements are initially set equal to 0. Then, four of its elements (indicating the starting position of bands for explicit offsets) are modified as follows:

```
for( k = 0; k < 4; k++ )
    bandTable[ ( k + saoLeftClass ) & 31 ] = k + 1                    (8-355)
```

4. The variable bandIdx is set equal to bandTable[ recPicture[ $xS_i$ ][ $yS_j$ ] >> bandShift ].

5. The modified picture sample array saoPicture[ $xS_i$ ][ $yS_j$ ] is derived as follows:

$$\begin{aligned}\text{saoPicture}[\ xS_i\ ][\ yS_j\ ] = \text{Clip3}(\ 0, (\ 1\ <<\ \text{bitDepth}\ ) - 1, &\text{recPicture}[\ xS_i\ ][\ yS_j\ ] + \\ &\text{SaoOffsetVal}[\ \text{cIdx}\ ][\ \text{rx}\ ][\ \text{ry}\ ][\ \text{bandIdx}\ ]\ )\end{aligned} \qquad (8\text{-}356)$$

**Table 8-12 – Specification of hPos and vPos according to the sample adaptive offset class**

| SaoEoClass[ cIdx ][ rx ][ ry ] | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| hPos[ 0 ] | −1 | 0 | −1 | 1 |
| hPos[ 1 ] | 1 | 0 | 1 | −1 |
| vPos[ 0 ] | 0 | −1 | −1 | −1 |
| vPos[ 1 ] | 0 | 1 | 1 | 1 |

# 9 Parsing process

## 9.1 General

Inputs to this process are bits from the RBSP.

Outputs of this process are syntax element values.

This process is invoked when the descriptor of a syntax element in the syntax tables in subclause 7.3 is equal to ue(v), se(v) (see subclause 9.2), or ae(v) (see subclause 9.3).

## 9.2 Parsing process for 0-th order Exp-Golomb codes

### 9.2.1 General

This process is invoked when the descriptor of a syntax element in the syntax tables in subclause 7.3 is equal to ue(v) or se(v).

Inputs to this process are bits from the RBSP.

Outputs of this process are syntax element values.

Syntax elements coded as ue(v) or se(v) are Exp-Golomb-coded. 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++ )                                        (9-1)
    b = read_bits( 1 )
```

The variable codeNum is then assigned as follows:

$$\text{codeNum} = 2^{\text{leadingZeroBits}} - 1 + \text{read\_bits( leadingZeroBits )} \qquad (9\text{-}2)$$

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 9-1 illustrates the structure of the Exp-Golomb code by separating the bit string into "prefix" and "suffix" bits. The "prefix" bits are those bits that are parsed as specified above for the computation of leadingZeroBits, and are shown as either 0 or 1 in the bit string column of Table 9-1. The "suffix" bits are those bits that are parsed in the computation of codeNum and are shown as $x_i$ in Table 9-1, with i in the range of 0 to leadingZeroBits − 1, inclusive. Each $x_i$ is equal to either 0 or 1.

**Table 9-1 – 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 9-2 illustrates explicitly the assignment of bit strings to codeNum values.

**Table 9-2 – 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 subclause 9.2.2 with codeNum as input.

### 9.2.2 Mapping process for signed Exp-Golomb codes

Input to this process is codeNum as specified in subclause 9.2.

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 9-3 provides the assignment rule.

**Table 9-3 – 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 ) |

## 9.3 CABAC parsing process for slice segment data

### 9.3.1 General

This process is invoked when parsing syntax elements with descriptor ae(v) in subclauses 7.3.8.1 through 7.3.8.11.

Inputs to this process are a request for a value of a syntax element and values of prior parsed syntax elements.

Output of this process is the value of the syntax element.

The initialization process of the CABAC parsing process as specified in subclause 9.3.2 is invoked when starting the parsing of one or more of the following:

– the slice segment data syntax specified in subclause 7.3.8.1

– the coding tree unit syntax specified in subclause 7.3.8.2 and the coding tree unit is the first coding tree unit in a tile

– the coding tree unit syntax specified in subclause 7.3.8.2, entropy_coding_sync_enabled_flag is equal to 1, and the associated luma coding tree block is the first luma coding tree block in a coding tree unit row

The parsing of syntax elements proceeds as follows:

For each requested value of a syntax element a binarization is derived as specified in subclause 9.3.3.

The binarization for the syntax element and the sequence of parsed bins determines the decoding process flow as described in subclause 9.3.4.

In case the request for a value of a syntax element is processed for the syntax element pcm_flag and the decoded value of pcm_flag is equal to 1, the decoding engine is initialized after the decoding of any pcm_alignment_zero_bit and all pcm_sample_luma and pcm_sample_chroma data as specified in subclause 9.3.2.5.

The storage process for context variables is applied as follows:

– When ending the parsing of the coding tree unit syntax in subclause 7.3.8.2, entropy_coding_sync_enabled_flag is equal to 1 and CtbAddrInRs % PicWidthInCtbsY is equal to 1, the storage process for context variables as specified in subclause 9.3.2.3 is invoked with TableStateIdxWpp and TableMpsValWpp as outputs.

– When ending the parsing of the general slice segment data syntax in subclause 7.3.8.1, dependent_slice_segments_enabled_flag is equal to 1 and end_of_slice_segment_flag is equal to 1, the storage process for context variables as specified in subclause 9.3.2.3 is invoked with TableStateIdxDs and TableMpsValDs as outputs.

The whole CABAC parsing process for a syntax element synEl is illustrated in Figure 9-1.

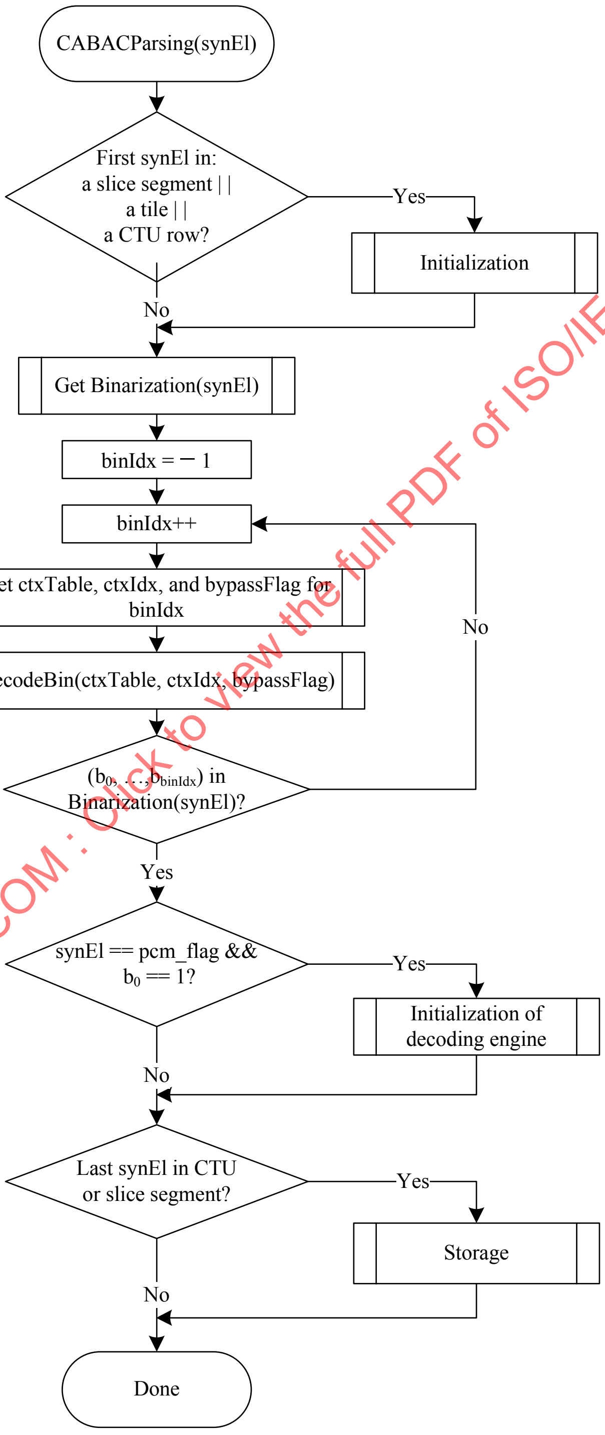

CABACParsing(synEl)
First synEl in: a slice segment | | a tile | | a CTU row?
Yes
Initialization
No
Get Binarization(synEl)
binIdx = − 1
binIdx++
Get ctxTable, ctxIdx, and bypassFlag for binIdx
DecodeBin(ctxTable, ctxIdx, bypassFlag)
No
(b0, …, bbinIdx) in Binarization(synEl)?
Yes
synEl == pcm_flag && b0 == 1?
Yes
Initialization of decoding engine
No
Last synEl in CTU or slice segment?
Yes
Storage
No
Done

**Figure 9-1 – Illustration of CABAC parsing process for a syntax element synEl (informative)**

### 9.3.2 Initialization process

#### 9.3.2.1 General

Outputs of this process are initialized CABAC internal variables.

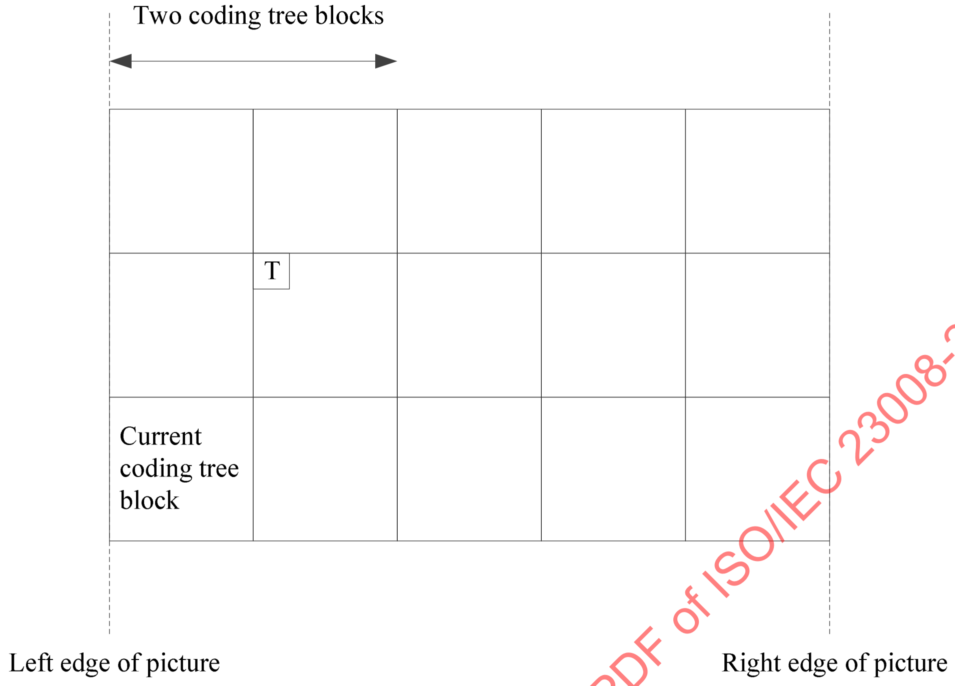


**Figure 9-2 – Spatial neighbour T that is used to invoke the coding tree block availability derivation process relative to the current coding tree block (informative)**

The context variables of the arithmetic decoding engine are initialized as follows:

– If the coding tree unit is the first coding tree unit in a tile, the initialization process for context variables is invoked as specified in subclause 9.3.2.2.

– Otherwise, if entropy_coding_sync_enabled_flag is equal to 1 and CtbAddrInRs % PicWidthInCtbsY is equal to 0, the following applies:

  – The location ( xNbT, yNbT ) of the top-left luma sample of the spatial neighbouring block T (Figure 9-2) is derived using the location ( x0, y0 ) of the top-left luma sample of the current coding tree block as follows:

$$( xNbT, yNbT ) = ( x0 + CtbSizeY, y0 - CtbSizeY ) \qquad (9\text{-}3)$$

  – The availability derivation process for a block in z-scan order as specified in subclause 6.4.1 is invoked with the location ( xCurr, yCurr ) set equal to ( x0, y0 ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xNbT, yNbT ) as inputs, and the output is assigned to availableFlagT.

  – The synchronization process for context variables is invoked as follows:

    – If availableFlagT is equal to 1, the synchronization process for context variables as specified in subclause 9.3.2.4 is invoked with TableStateIdxWpp and TableMpsValWpp as inputs.

    – Otherwise, the initialization process for context variables is invoked as specified in subclause 9.3.2.2.

– Otherwise, if CtbAddrInRs is equal to slice_segment_address and dependent_slice_segment_flag is equal to 1, the synchronization process for context variables as specified in subclause 9.3.2.4 is invoked with TableStateIdxDs and TableMpsValDs as inputs.

– Otherwise, the initialization process for context variables is invoked as specified in subclause 9.3.2.2.

The initialization process for the arithmetic decoding engine is invoked as specified in subclause 9.3.2.5.

The whole initialization process for a syntax element synEl is illustrated in the flowchart of Figure 9-3.

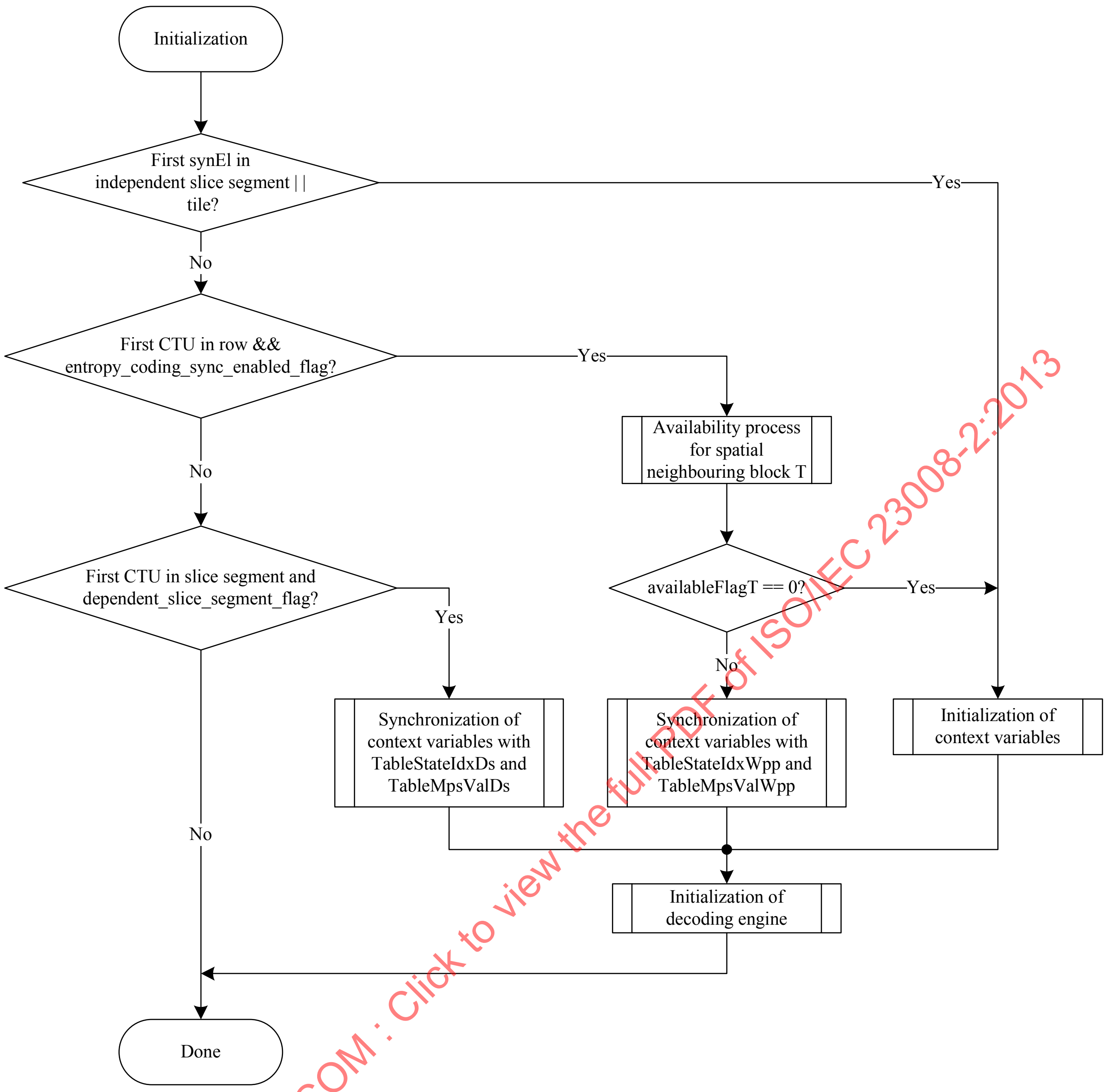

Initialization
First synEl in independent slice segment | | tile?
Yes
No
First CTU in row && entropy_coding_sync_enabled_flag?
Yes
No
Availability process for spatial neighbouring block T
First CTU in slice segment and dependent_slice_segment_flag?
availableFlagT == 0?
Yes
Yes
No
Synchronization of context variables with TableStateIdxDs and TableMpsValDs
Synchronization of context variables with TableStateIdxWpp and TableMpsValWpp
Initialization of context variables
No
Initialization of decoding engine
Done

**Figure 9-3 – Illustration of CABAC initialization process (informative)**

### 9.3.2.2 Initialization process for context variables

Outputs of this process are the initialized CABAC context variables indexed by ctxTable and ctxIdx.

Table 9-5 to Table 9-31 contain the values of the 8 bit variable initValue used in the initialization of context variables that are assigned to all syntax elements in subclauses 7.3.8.1 through 7.3.8.11, except end_of_slice_segment_flag, end_of_sub_stream_one_bit, and pcm_flag.

For each context variable, the two variables pStateIdx and valMps are initialized.

NOTE 1 – The variable pStateIdx corresponds to a probability state index and the variable valMps corresponds to the value of the most probable symbol as further described in subclause 9.3.4.3.

From the 8 bit table entry initValue, the two 4 bit variables slopeIdx and offsetIdx are derived as follows:

$$\begin{aligned}&\text{slopeIdx} = \text{initValue} \gg 4\\&\text{offsetIdx} = \text{initValue} \,\&\, 15\end{aligned} \qquad (9\text{-}4)$$

The variables m and n, used in the initialization of context variables, are derived from slopeIdx and offsetIdx as follows:

$$\begin{aligned}&m = \text{slopeIdx} * 5 - 45\\&n = ( \text{offsetIdx} \ll 3 ) - 16\end{aligned} \qquad (9\text{-}5)$$

The two values assigned to pStateIdx and valMps for the initialization are derived from $\text{SliceQp}_Y$, which is derived in Equation 7-40. Given the variables m and n, the initialization is specified as follows:

```
preCtxState = Clip3( 1, 126, ( ( m * Clip3( 0, 51, SliceQpY ) ) >> 4 ) + n )
valMps = ( preCtxState <= 63 ) ? 0 : 1
pStateIdx = valMps ? ( preCtxState − 64 ) : ( 63 − preCtxState )          (9-6)
```

In Table 9-4, the ctxIdx for which initialization is needed for each of the three initialization types, specified by the variable initType, are listed. Also listed is the table number that includes the values of initValue needed for the initialization. For P and B slice types, the derivation of initType depends on the value of the cabac_init_flag syntax element. The variable initType is derived as follows:

```
if( slice_type = = I )
    initType = 0
else if( slice_type = = P )
    initType = cabac_init_flag ? 2 : 1                                    (9-7)
else
    initType = cabac_init_flag ? 1 : 2
```

**Table 9-4 – Association of ctxIdx and syntax elements for each initializationType in the initialization process**

| Syntax structure | Syntax element | ctxTable | initType | | |
|---|---|---|---|---|---|
| | | | **0** | **1** | **2** |
| sao( ) | sao_merge_left_flag<br>sao_merge_up_flag | Table 9-5 | 0 | 1 | 2 |
| | sao_type_idx_luma<br>sao_type_idx_chroma | Table 9-6 | 0 | 1 | 2 |
| coding_quadtree( ) | split_cu_flag[ ][ ] | Table 9-7 | 0..2 | 3..5 | 6..8 |
| coding_unit( ) | cu_transquant_bypass_flag | Table 9-8 | 0 | 1 | 2 |
| | cu_skip_flag | Table 9-9 | | 0..2 | 3..5 |
| | pred_mode_flag | Table 9-10 | | 0 | 1 |
| | part_mode | Table 9-11 | 0 | 1..4 | 5..8 |
| | prev_intra_luma_pred_flag[ ][ ] | Table 9-12 | 0 | 1 | 2 |
| | intra_chroma_pred_mode[ ][ ] | Table 9-13 | 0 | 1 | 2 |
| | rqt_root_cbf | Table 9-14 | | 0 | 1 |
| prediction_unit( ) | merge_flag[ ][ ] | Table 9-15 | | 0 | 1 |
| | merge_idx[ ][ ] | Table 9-16 | | 0 | 1 |
| | inter_pred_idc[ ][ ] | Table 9-17 | | 0..4 | 5..9 |
| | ref_idx_l0[ ][ ], ref_idx_l1[ ][ ] | Table 9-18 | | 0..1 | 2..3 |
| | mvp_l0_flag[ ][ ],<br>mvp_l1_flag[ ][ ] | Table 9-19 | | 0 | 1 |
| transform_tree( ) | split_transform_flag[ ][ ][ ] | Table 9-20 | 0..2 | 3..5 | 6..8 |
| | cbf_luma[ ][ ][ ] | Table 9-21 | 0..1 | 2..3 | 4..5 |
| | cbf_cb[ ][ ][ ], cbf_cr[ ][ ][ ] | Table 9-22 | 0..3 | 4..7 | 8..11 |
| mvd_coding( ) | abs_mvd_greater0_flag[ ] | Table 9-23 | | 0 | 2 |
| | abs_mvd_greater1_flag[ ] | Table 9-23 | | 1 | 3 |
| transform_unit( ) | cu_qp_delta_abs | Table 9-24 | 0..1 | 2..3 | 4..5 |
| residual_coding( ) | transform_skip_flag[ ][ ][ 0 ] | Table 9-25 | 0 | 1 | 2 |
| | transform_skip_flag[ ][ ][ 1 ]<br>transform_skip_flag[ ][ ][ 2 ] | Table 9-25 | 3 | 4 | 5 |
| | last_sig_coeff_x_prefix | Table 9-26 | 0..17 | 18..35 | 36..53 |
| | last_sig_coeff_y_prefix | Table 9-27 | 0..17 | 18..35 | 36..53 |
| | coded_sub_block_flag[ ][ ] | Table 9-28 | 0..3 | 4..7 | 8..11 |
| | sig_coeff_flag[ ][ ] | Table 9-29 | 0..41 | 42..83 | 84..125 |
| | coeff_abs_level_greater1_flag[ ] | Table 9-30 | 0..23 | 24..47 | 48..71 |
| | coeff_abs_level_greater2_flag[ ] | Table 9-31 | 0..5 | 6..11 | 12..17 |

NOTE 2 – ctxTable equal to 0 and ctxIdx equal to 0 are associated with end_of_slice_segment_flag, end_of_sub_stream_one_bit, and pcm_flag. The decoding process specified in subclause 9.3.4.3.5 applies to ctxTable equal to 0 and ctxIdx equal to 0. This decoding process, however, may also be implemented by using the decoding process specified in subclause 9.3.4.3.2. In this case, the initial values associated with ctxTable equal to 0 and ctxIdx equal to 0 are specified to be pStateIdx = 63 and valMps = 0, where pStateIdx = 63 represents a non-adapting probability state.

**Table 9-5 – Values of initValue for ctxIdx of sao_merge_left_flag and sao_merge_up_flag**

| Initialization variable | ctxIdx of sao_merge_left_flag and sao_merge_up_flag | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| initValue | 153 | 153 | 153 |

**Table 9-6 – Values of initValue for ctxIdx of sao_type_idx_luma and sao_type_idx_chroma**

| Initialization variable | ctxIdx of sao_type_idx_luma and sao_type_idx_chroma | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| initValue | 200 | 185 | 160 |

**Table 9-7 – Values of initValue for ctxIdx of split_cu_flag**

| Initialization variable | ctxIdx of split_cu_flag | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| initValue | 139 | 141 | 157 | 107 | 139 | 126 | 107 | 139 | 126 |

**Table 9-8 – Values of initValue for ctxIdx of cu_transquant_bypass_flag**

| Initialization variable | ctxIdx of cu_transquant_bypass_flag | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| initValue | 154 | 154 | 154 |

**Table 9-9 – Values of initValue for ctxIdx of cu_skip_flag**

| Initialization variable | ctxIdx of cu_skip_flag | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| initValue | 197 | 185 | 201 | 197 | 185 | 201 |

**Table 9-10 – Values of initValue for ctxIdx of pred_mode_flag**

| Initialization variable | ctxIdx of pred_mode_flag | |
|---|---|---|
| | 0 | 1 |
| initValue | 149 | 134 |

**Table 9-11 – Values of initValue for ctxIdx of part_mode**

| Initialization variable | ctxIdx of part_mode | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| initValue | 184 | 154 | 139 | 154 | 154 | 154 | 139 | 154 | 154 |

**Table 9-12 – Values of initValue for ctxIdx of prev_intra_luma_pred_flag**

| Initialization variable | ctxIdx of prev_intra_luma_pred_flag | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| initValue | 184 | 154 | 183 |

**Table 9-13 – Values of initValue for ctxIdx of intra_chroma_pred_mode**

| Initialization variable | ctxIdx of intra_chroma_pred_mode | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| initValue | 63 | 152 | 152 |

**Table 9-14 – Values of initValue for ctxIdx of rqt_root_cbf**

| Initialization variable | ctxIdx of rqt_root_cbf | |
|---|---|---|
| | 0 | 1 |
| initValue | 79 | 79 |

**Table 9-15 – Value of initValue for ctxIdx of merge_flag**

| Initialization variable | ctxIdx of merge_flag | |
|---|---|---|
| | 0 | 1 |
| initValue | 110 | 154 |

**Table 9-16 – Values of initValue for ctxIdx of merge_idx**

| Initialization variable | ctxIdx of merge_idx | |
|---|---|---|
| | 0 | 1 |
| initValue | 122 | 137 |

**Table 9-17 – Values of initValue for ctxIdx of inter_pred_idc**

| Initialization variable | ctxIdx of inter_pred_idc | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| initValue | 95 | 79 | 63 | 31 | 31 | 95 | 79 | 63 | 31 | 31 |

**Table 9-18 – Values of initValue for ctxIdx of ref_idx_l0 and ref_idx_l1**

| Initialization variable | ctxIdx of ref_idx_l0 and ref_idx_l1 | | | |
|---|---|---|---|---|
| | 0 | 1 | 2 | 3 |
| initValue | 153 | 153 | 153 | 153 |

**Table 9-19 – Values of initValue for ctxIdx of mvp_l0_flag and mvp_l1_flag**

| Initialization variable | ctxIdx of mvp_l0_flag and mvp_l1_flag | |
|---|---|---|
| | 0 | 1 |
| initValue | 168 | 168 |

**Table 9-20 – Values of initValue for ctxIdx of split_transform_flag**

| Initialization variable | ctxIdx of split_transform_flag | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| initValue | 153 | 138 | 138 | 124 | 138 | 94 | 224 | 167 | 122 |

**Table 9-21 – Values of initValue for ctxIdx of cbf_luma**

| Initialization variable | ctxIdx of cbf_luma | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 |
| initValue | 111 | 141 | 153 | 111 | 153 | 111 |

**Table 9-22 – Values of initValue for ctxIdx of cbf_cb and cbf_cr**

| Initialization variable | ctxIdx of cbf_cb and cbf_cr | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| initValue | 94 | 138 | 182 | 154 | 149 | 107 | 167 | 154 | 149 | 92 | 167 | 154 |

**Table 9-23 – Values of initValue for ctxIdx of abs_mvd_greater0_flag and abs_mvd_greater1_flag**

| Initialization variable | ctxIdx of abs_mvd_greater0_flag and abs_mvd_greater1_flag | | | |
|---|---|---|---|---|
| | **0** | **1** | **2** | **3** |
| **initValue** | 140 | 198 | 169 | 198 |

**Table 9-24 – Values of initValue for ctxIdx of cu_qp_delta_abs**

| Initialization variable | ctxIdx of cu_qp_delta_abs | | | | | |
|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** |
| **initValue** | 154 | 154 | 154 | 154 | 154 | 154 |

**Table 9-25 – Values of initValue for ctxIdx of transform_skip_flag**

| Initialization variable | ctxIdx of transform_skip_flag | | | | | |
|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** |
| **initValue** | 139 | 139 | 139 | 139 | 139 | 139 |

**Table 9-26 – Values of initValue for ctxIdx of last_sig_coeff_x_prefix**

| Initialization variable | ctxIdx of last_sig_coeff_x_prefix | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
| **initValue** | 110 | 110 | 124 | 125 | 140 | 153 | 125 | 127 | 140 | 109 | 111 | 143 | 127 | 111 | 79 | 108 | 123 | 63 |
| | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** | **35** |
| **initValue** | 125 | 110 | 94 | 110 | 95 | 79 | 125 | 111 | 110 | 78 | 110 | 111 | 111 | 95 | 94 | 108 | 123 | 108 |
| | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** | **48** | **49** | **50** | **51** | **52** | **53** |
| **initValue** | 125 | 110 | 124 | 110 | 95 | 94 | 125 | 111 | 111 | 79 | 125 | 126 | 111 | 111 | 79 | 108 | 123 | 93 |

**Table 9-27 – Values of initValue for ctxIdx of last_sig_coeff_y_prefix**

| Initialization variable | ctxIdx of last_sig_coeff_y_prefix | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
| **initValue** | 110 | 110 | 124 | 125 | 140 | 153 | 125 | 127 | 140 | 109 | 111 | 143 | 127 | 111 | 79 | 108 | 123 | 63 |
| | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** | **32** | **33** | **34** | **35** |
| **initValue** | 125 | 110 | 94 | 110 | 95 | 79 | 125 | 111 | 110 | 78 | 110 | 111 | 111 | 95 | 94 | 108 | 123 | 108 |
| | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** | **48** | **49** | **50** | **51** | **52** | **53** |
| **initValue** | 125 | 110 | 124 | 110 | 95 | 94 | 125 | 111 | 111 | 79 | 125 | 126 | 111 | 111 | 79 | 108 | 123 | 93 |

**Table 9-28 – Values of initValue for ctxIdx of coded_sub_block_flag**

| Initialization variable | ctxIdx of coded_sub_block_flag | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** |
| **initValue** | 91 | 171 | 134 | 141 | 121 | 140 | 61 | 154 | 121 | 140 | 61 | 154 |

**Table 9-29 – Values of initValue for ctxIdx of sig_coeff_flag**

| Initialization variable | ctxIdx of sig_coeff_flag | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **initValue** | 111 | 111 | 125 | 110 | 110 | 94 | 124 | 108 | 124 | 107 | 125 | 141 | 179 | 153 | 125 | 107 |
| | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** |
| **initValue** | 125 | 141 | 179 | 153 | 125 | 107 | 125 | 141 | 179 | 153 | 125 | 140 | 139 | 182 | 182 | 152 |
| | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** |
| **initValue** | 136 | 152 | 136 | 153 | 136 | 139 | 111 | 136 | 139 | 111 | 155 | 154 | 139 | 153 | 139 | 123 |
| | **48** | **49** | **50** | **51** | **52** | **53** | **54** | **55** | **56** | **57** | **58** | **59** | **60** | **61** | **62** | **63** |
| **initValue** | 123 | 63 | 153 | 166 | 183 | 140 | 136 | 153 | 154 | 166 | 183 | 140 | 136 | 153 | 154 | 166 |
| | **64** | **65** | **66** | **67** | **68** | **69** | **70** | **71** | **72** | **73** | **74** | **75** | **76** | **77** | **78** | **79** |
| **initValue** | 183 | 140 | 136 | 153 | 154 | 170 | 153 | 123 | 123 | 107 | 121 | 107 | 121 | 167 | 151 | 183 |
| | **80** | **81** | **82** | **83** | **84** | **85** | **86** | **87** | **88** | **89** | **90** | **91** | **92** | **93** | **94** | **95** |
| **initValue** | 140 | 151 | 183 | 140 | 170 | 154 | 139 | 153 | 139 | 123 | 123 | 63 | 124 | 166 | 183 | 140 |
| | **96** | **97** | **98** | **99** | **100** | **101** | **102** | **103** | **104** | **105** | **106** | **107** | **108** | **109** | **110** | **111** |
| **initValue** | 136 | 153 | 154 | 166 | 183 | 140 | 136 | 153 | 154 | 166 | 183 | 140 | 136 | 153 | 154 | 170 |
| | **112** | **113** | **114** | **115** | **116** | **117** | **118** | **119** | **120** | **121** | **122** | **123** | **124** | **125** | | |
| **initValue** | 153 | 138 | 138 | 122 | 121 | 122 | 121 | 167 | 151 | 183 | 140 | 151 | 183 | 140 | | |

**Table 9-30 – Values of initValue for ctxIdx of coeff_abs_level_greater1_flag**

| Initialization variable | ctxIdx of coeff_abs_level_greater1_flag | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **initValue** | 140 | 92 | 137 | 138 | 140 | 152 | 138 | 139 | 153 | 74 | 149 | 92 | 139 | 107 | 122 | 152 |
| | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** |
| **initValue** | 140 | 179 | 166 | 182 | 140 | 227 | 122 | 197 | 154 | 196 | 196 | 167 | 154 | 152 | 167 | 182 |
| | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** |
| **initValue** | 182 | 134 | 149 | 136 | 153 | 121 | 136 | 137 | 169 | 194 | 166 | 167 | 154 | 167 | 137 | 182 |
| | **48** | **49** | **50** | **51** | **52** | **53** | **54** | **55** | **56** | **57** | **58** | **59** | **60** | **61** | **62** | **63** |
| **initValue** | 154 | 196 | 167 | 167 | 154 | 152 | 167 | 182 | 182 | 134 | 149 | 136 | 153 | 121 | 136 | 122 |
| | **64** | **65** | **66** | **67** | **68** | **69** | **70** | **71** | | | | | | | | |
| **initValue** | 169 | 208 | 166 | 167 | 154 | 152 | 167 | 182 | | | | | | | | |

**Table 9-31 – Values of initValue for ctxIdx of coeff_abs_level_greater2_flag**

| Initialization variable | ctxIdx of coeff_abs_level_greater2_flag | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **initValue** | 138 | 153 | 136 | 167 | 152 | 152 | 107 | 167 | 91 |
| | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
| **initValue** | 122 | 107 | 167 | 107 | 167 | 91 | 107 | 107 | 167 |

### 9.3.2.3 Storage process for context variables

Inputs to this process are the CABAC context variables indexed by ctxTable and ctxIdx.

Outputs of this process are variables tableStateSync and tableMPSSync containing the values of the variables pStateIdx and valMps used in the initialization process of context variables that are assigned to all syntax elements in subclauses 7.3.8.1 through 7.3.8.11, except end_of_slice_segment_flag, end_of_sub_stream_one_bit, and pcm_flag.

For each context variable, the corresponding entries pStateIdx and valMps of tables tableStateSync and tableMPSSync are initialized to the corresponding pStateIdx and valMps.

The storage process for context variables is illustrated in the flowchart of Figure 9-4.

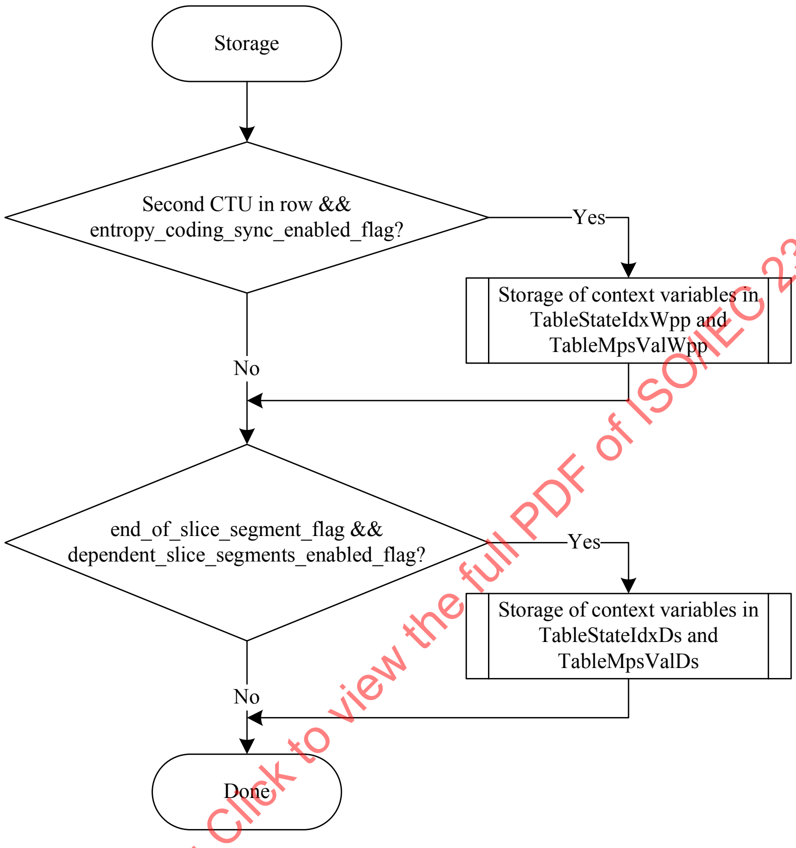

Storage
Second CTU in row && entropy_coding_sync_enabled_flag?
Yes
Storage of context variables in TableStateIdxWpp and TableMpsValWpp
No
end_of_slice_segment_flag && dependent_slice_segments_enabled_flag?
Yes
Storage of context variables in TableStateIdxDs and TableMpsValDs
No
Done

**Figure 9-4 – Illustration of CABAC storage process (informative)**

### 9.3.2.4 Synchronization process for context variables

Inputs to this process are variables tableStateSync and tableMPSSync containing the values of the variables pStateIdx and valMps used in the storage process of context variables that are assigned to all syntax elements in subclauses 7.3.8.1 through 7.3.8.11, except end_of_slice_segment_flag, end_of_sub_stream_one_bit, and pcm_flag.

Outputs of this process are the initialized CABAC context variables indexed by ctxTable and ctxIdx.

For each context variable, the corresponding context variables pStateIdx and valMps are initialized to the corresponding entries pStateIdx and valMps of tables tableStateSync and tableMPSSync.

### 9.3.2.5 Initialization process for the arithmetic decoding engine

Outputs of this process are the initialized decoding engine registers ivlCurrRange and ivlOffset both in 16 bit register precision.

The status of the arithmetic decoding engine is represented by the variables ivlCurrRange and ivlOffset. In the initialization procedure of the arithmetic decoding process, ivlCurrRange is set equal to 510 and ivlOffset is set equal to the value returned from read_bits( 9 ) interpreted as a 9 bit binary representation of an unsigned integer with the most significant bit written first.

The bitstream shall not contain data that result in a value of ivlOffset being equal to 510 or 511.

NOTE – The description of the arithmetic decoding engine in this Specification utilizes 16 bit register precision. However, a minimum register precision of 9 bits is required for storing the values of the variables ivlCurrRange and ivlOffset after invocation of the arithmetic decoding process (DecodeBin) as specified in subclause 9.3.4.3. The arithmetic decoding process for a binary decision (DecodeDecision) as specified in subclause 9.3.4.3.2 and the decoding process for a binary decision before termination (DecodeTerminate) as specified in subclause 9.3.4.3.5 require a minimum register precision of 9 bits for the variables ivlCurrRange and ivlOffset. The bypass decoding process for binary decisions (DecodeBypass) as specified in subclause 9.3.4.3.4 requires a minimum register precision of 10 bits for the variable ivlOffset and a minimum register precision of 9 bits for the variable ivlCurrRange.

### 9.3.3 Binarization process

#### 9.3.3.1 General

Input to this process is a request for a syntax element.

Output of this process is the binarization of the syntax element.

Table 9-32 specifies the type of binarization process associated with each syntax element and corresponding inputs.

The specification of the truncated Rice (TR) binarization process, the k-th order Exp-Golomb (EGk) binarization process, and the fixed-length (FL) binarization process are given in subclauses 9.3.3.2 through 9.3.3.4, respectively. Other binarizations are specified in subclauses 9.3.3.5 through 9.3.3.9.

**Table 9-32 – Syntax elements and associated binarizations**

| Syntax structure | Syntax element | Binarization | |
|---|---|---|---|
| | | Process | Input parameters |
| slice_segment_data( ) | end_of_slice_segment_flag | FL | cMax = 1 |
| | end_of_sub_stream_one_bit | FL | cMax = 1 |
| sao( ) | sao_merge_left_flag | FL | cMax = 1 |
| | sao_merge_up_flag | FL | cMax = 1 |
| | sao_type_idx_luma | TR | cMax = 2, cRiceParam = 0 |
| | sao_type_idx_chroma | TR | cMax = 2, cRiceParam = 0 |
| | sao_offset_abs[ ][ ][ ][ ] | TR | cMax = ( 1 << ( Min( bitDepth, 10 ) − 5 ) ) − 1, cRiceParam = 0 |
| | sao_offset_sign[ ][ ][ ][ ] | FL | cMax = 1 |
| | sao_band_position[ ][ ][ ] | FL | cMax = 31 |
| | sao_eo_class_luma | FL | cMax = 3 |
| | sao_eo_class_chroma | FL | cMax = 3 |
| coding_quadtree( ) | split_cu_flag[ ][ ] | FL | cMax = 1 |
| coding_unit( ) | cu_transquant_bypass_flag | FL | cMax = 1 |
| | cu_skip_flag | FL | cMax = 1 |
| | pred_mode_flag | FL | cMax = 1 |
| | part_mode | 9.3.3.5 | ( xCb, yCb ) = ( x0, y0), log2CbSize |
| | pcm_flag[ ][ ] | FL | cMax = 1 |
| | prev_intra_luma_pred_flag[ ][ ] | FL | cMax = 1 |
| | mpm_idx[ ][ ] | TR | cMax = 2, cRiceParam = 0 |
| | rem_intra_luma_pred_mode[ ][ ] | FL | cMax = 31 |
| | intra_chroma_pred_mode[ ][ ] | 9.3.3.6 | - |
| | rqt_root_cbf | FL | cMax = 1 |

**Table 9-32 – Syntax elements and associated binarizations**

| Syntax structure | Syntax element | Binarization | |
|---|---|---|---|
| | | Process | Input parameters |
| prediction_unit( ) | merge_flag[ ][ ] | FL | cMax = 1 |
| | merge_idx[ ][ ] | TR | cMax = MaxNumMergeCand − 1, cRiceParam = 0 |
| | inter_pred_idc[ x0 ][ y0 ] | 9.3.3.7 | nPbW, nPbH |
| | ref_idx_l0[ ][ ] | TR | cMax = num_ref_idx_l0_active_minus1, cRiceParam = 0 |
| | mvp_l0_flag[ ][ ] | FL | cMax = 1 |
| | ref_idx_l1[ ][ ] | TR | cMax = num_ref_idx_l1_active_minus1, cRiceParam = 0 |
| | mvp_l1_flag[ ][ ] | FL | cMax = 1 |
| transform_tree( ) | split_transform_flag[ ][ ][ ] | FL | cMax = 1 |
| | cbf_luma[ ][ ][ ] | FL | cMax = 1 |
| | cbf_cb[ ][ ][ ] | FL | cMax = 1 |
| | cbf_cr[ ][ ][ ] | FL | cMax = 1 |
| mvd_coding( ) | abs_mvd_greater0_flag[ ] | FL | cMax = 1 |
| | abs_mvd_greater1_flag[ ] | FL | cMax = 1 |
| | abs_mvd_minus2[ ] | EG1 | - |
| | mvd_sign_flag[ ] | FL | cMax = 1 |
| transform_unit( ) | cu_qp_delta_abs | 9.3.3.8 | - |
| | cu_qp_delta_sign_flag | FL | cMax = 1 |
| residual_coding( ) | transform_skip_flag[ ][ ][ ] | FL | cMax = 1 |
| | last_sig_coeff_x_prefix | TR | cMax = ( log2TrafoSize << 1 ) − 1, cRiceParam = 0 |
| | last_sig_coeff_y_prefix | TR | cMax = ( log2TrafoSize << 1 ) − 1, cRiceParam = 0 |
| | last_sig_coeff_x_suffix | FL | cMax = ( 1 << ( ( last_sig_coeff_x_prefix >> 1 ) − 1 ) − 1 ) |
| | last_sig_coeff_y_suffix | FL | cMax = ( 1 << ( ( last_sig_coeff_y_prefix >> 1 ) − 1 ) − 1 ) |
| | coded_sub_block_flag[ ][ ] | FL | cMax = 1 |
| | sig_coeff_flag[ ][ ] | FL | cMax = 1 |
| | coeff_abs_level_greater1_flag[ ] | FL | cMax = 1 |
| | coeff_abs_level_greater2_flag[ ] | FL | cMax = 1 |
| | coeff_abs_level_remaining[ ] | 9.3.3.9 | current sub-block scan index i, baseLevel |
| | coeff_sign_flag[ ] | FL | cMax = 1 |

### 9.3.3.2 Truncated Rice (TR) binarization process

Input to this process is a request for a TR binarization for a syntax element with value synVal, cMax, and cRiceParam.

Output of this process is the TR binarization of the syntax element.

A TR bin string is a concatenation of a prefix bin string and, when present, a suffix bin string.

For the derivation of the prefix bin string, the following applies:

– The prefix value of synVal, prefixVal, is derived as follows:

$$\text{prefixVal} = \text{synVal} \gg \text{cRiceParam} \quad (9\text{-}8)$$

– The prefix of the TR bin string is specified as follows:

  – If prefixVal is less than cMax >> cRiceParam, the prefix bin string is a bit string of length prefixVal + 1 indexed by binIdx. The bins for binIdx less than prefixVal are equal to 1. The bin with binIdx equal to prefixVal is equal to 0. Table 9-33 illustrates the bin strings of this unary binarization for prefixVal.

  – Otherwise, the bin string is a bit string of length cMax >> cRiceParam with all bins being equal to 1.

**Table 9-33 – Bin string of the unary binarization (informative)**

| **prefixVal** | **Bin string** | | | | | |
|---|---|---|---|---|---|---|
| 0 | 0 | | | | | |
| 1 | 1 | 0 | | | | |
| 2 | 1 | 1 | 0 | | | |
| 3 | 1 | 1 | 1 | 0 | | |
| 4 | 1 | 1 | 1 | 1 | 0 | |
| 5 | 1 | 1 | 1 | 1 | 1 | 0 |
| … | | | | | | |
| binIdx | 0 | 1 | 2 | 3 | 4 | 5 |

When cMax is greater than synVal, the suffix of the TR bin string is present and it is derived as follows:

– The suffix value of synVal, suffixVal, is derived as follows:

$$\text{suffixVal} = \text{synVal} - ( ( \text{prefixVal} ) \ll \text{cRiceParam} ) \quad (9\text{-}9)$$

– The suffix of the TR bin string is specified by the binary representation of suffixVal.

NOTE – For the input parameter cRiceParam = 0 the TR binarization is exactly a truncated unary binarization and it is always invoked with a cMax value equal to the largest possible value of the syntax element being decoded.

### 9.3.3.3 k-th order Exp-Golomb (EGk) binarization process

Inputs to this process is a request for an EGk binarization for a syntax element.

Output of this process is the EGk binarization of the syntax element.

The bin string of the EGk binarization process of a syntax element synVal is specified as follows, where each call of the function put( X ), with X being equal to 0 or 1, adds the binary value X at the end of the bin string:

```
absV = Abs( synVal )
stopLoop = 0
do {
    if( absV >= ( 1 << k ) ) {
        put( 1 )
        absV = absV − ( 1 << k )
        k++
    } else {
        put( 0 )                                        (9-10)
        while( k− − )
            put( ( absV >> k ) & 1 )
        stopLoop = 1
    }
} while( !stopLoop )
```

NOTE – The specification for the k-th order Exp-Golomb (EGk) code uses 1's and 0's in reverse meaning for the unary part of the Exp-Golomb code of 0-th order as specified in subclause 9.2.

### 9.3.3.4 Fixed-length (FL) binarization process

Inputs to this process are a request for a FL binarization for a syntax element and cMax.

Output of this process is the FL binarization of the syntax element.

FL binarization is constructed by using a fixedLength-bit unsigned integer bin string of the syntax element value, where fixedLength = Ceil( Log2( cMax + 1 ) ). The indexing of bins for the FL binarization is such that the binIdx = 0 relates to the most significant bit with increasing values of binIdx towards the least significant bit.

### 9.3.3.5 Binarization process for part_mode

Inputs to this process are a request for a binarization for the syntax element part_mode a luma location ( xCb, yCb ), specifying the top-left sample of the current luma coding block relative to the top-left luma sample of the current picture, and a variable log2CbSize specifying the current luma coding block size.

Output of this process is the binarization of the syntax element.

The binarization for the syntax element part_mode is specified in Table 9-34 depending on the values of CuPredMode[ xCb ][ yCb ] and log2CbSize.

**Table 9-34 – Binarization for part_mode**

| **CuPredMode[ xCb ][ yCb ]** | **part_mode** | **PartMode** | **Bin string** | | | |
|---|---|---|---|---|---|---|
| | | | log2CbSize > MinCbLog2SizeY | | log2CbSize == MinCbLog2SizeY | |
| | | | !amp_enabled_flag | amp_enabled_flag | log2CbSize == 3 | log2CbSize > 3 |
| MODE_INTRA | 0 | PART_2Nx2N | - | - | 1 | 1 |
| | 1 | PART_NxN | - | - | 0 | 0 |
| MODE_INTER | 0 | PART_2Nx2N | 1 | 1 | 1 | 1 |
| | 1 | PART_2NxN | 01 | 011 | 01 | 01 |
| | 2 | PART_Nx2N | 00 | 001 | 00 | 001 |
| | 3 | PART_NxN | - | - | - | 000 |
| | 4 | PART_2NxnU | - | 0100 | - | - |
| | 5 | PART_2NxnD | - | 0101 | - | - |
| | 6 | PART_nLx2N | - | 0000 | - | - |
| | 7 | PART_nRx2N | - | 0001 | - | - |

### 9.3.3.6 Binarization process for intra_chroma_pred_mode

Input to this process is a request for a binarization for the syntax element intra_chroma_pred_mode.

Output of this process is the binarization of the syntax element.

The binarization for the syntax element intra_chroma_pred_mode is specified in Table 9-35.

**Table 9-35 – Binarization for intra_chroma_pred_mode**

| Value of intra_chroma_pred_mode | Bin string |
|---|---|
| 4 | 0 |
| 0 | 100 |
| 1 | 101 |
| 2 | 110 |
| 3 | 111 |

### 9.3.3.7 Binarization process for inter_pred_idc

Inputs to this process are a request for a binarization for the syntax element inter_pred_idc, the current luma prediction block width nPbW, and the current luma prediction block height nPbH.

Output of this process is the binarization of the syntax element.

The binarization for the syntax element inter_pred_idc is specified in Table 9-36.

**Table 9-36 – Binarization for inter_pred_idc**

| Value of inter_pred_idc | Name of inter_pred_idc | Bin string | |
|---|---|---|---|
| | | ( nPbW + nPbH ) != 12 | ( nPbW + nPbH ) = = 12 |
| 0 | PRED_L0 | 00 | 0 |
| 1 | PRED_L1 | 01 | 1 |
| 2 | PRED_BI | 1 | - |

### 9.3.3.8 Binarization process for cu_qp_delta_abs

Input to this process is a request for a binarization for the syntax element cu_qp_delta_abs.

Output of this process is the binarization of the syntax element.

The binarization of the syntax element cu_qp_delta_abs is a concatenation of a prefix bin string and (when present) a suffix bin string.

For the derivation of the prefix bin string, the following applies:

– The prefix value of cu_qp_delta_abs, prefixVal, is derived as follows:

$$\text{prefixVal} = \text{Min}( \text{cu\_qp\_delta\_abs}, 5 ) \qquad (9\text{-}11)$$

– The prefix bin string is specified by invoking the TR binarization process as specified in subclause 9.3.3.2 for prefixVal with cMax = 5 and cRiceParam = 0.

When prefixVal is greater than 4, the suffix bin string is present and it is derived as follows:

– The suffix value of cu_qp_delta_abs, suffixVal, is derived as follows:

$$\text{suffixVal} = \text{cu\_qp\_delta\_abs} - 5 \qquad (9\text{-}12)$$

– The suffix bin string is specified by invoking the EGk binarization process as specified in subclause 9.3.3.3 for suffixVal with the Exp-Golomb order k set equal to 0.

### 9.3.3.9 Binarization process for coeff_abs_level_remaining

Input to this process is a request for a binarization for the syntax element coeff_abs_level_remaining[ n ], the current sub-block scan index i, and baseLevel.

Output of this process is the binarization of the syntax element.

The variables cLastAbsLevel and cLastRiceParam are derived as follows:

– If this process is invoked for the first time for the current sub-block scan index i, cLastAbsLevel and cLastRiceParam are set equal to 0.

– Otherwise (this process is not invoked for the first time for the current sub-block scan index i), cLastAbsLevel and cLastRiceParam are set equal to the values of cAbsLevel and cRiceParam, respectively, that have been derived during the last invocation of the binarization process for the syntax element coeff_abs_level_remaining as specified in this subclause.

The variable cAbsLevel is set equal to baseLevel + coeff_abs_level_remaining[ n ].

The variable cRiceParam is derived from cLastAbsLevel and cLastRiceParam as:

cRiceParam = Min( cLastRiceParam + ( cLastAbsLevel > ( 3 * ( 1 << cLastRiceParam ) ) ? 1 : 0 ), 4 ) (9-13)

The variable cMax is derived from cRiceParam as:

cMax = 4 << cRiceParam (9-14)

The binarization of the syntax element coeff_abs_level_remaining[ n ] is a concatenation of a prefix bin string and (when present) a suffix bin string.

For the derivation of the prefix bin string, the following applies:

– The prefix value of cu_qp_delta_abs, prefixVal, is derived as follows:

prefixVal = Min( cMax, coeff_abs_level_remaining[ n ] ) (9-15)

– The prefix bin string is specified by invoking the TR binarization process as specified in subclause 9.3.3.2 for prefixVal with the variables cMax and cRiceParam as inputs.

When the prefix bin string is equal to the bit string of length 4 with all bits equal to 1, the suffix bin string is present and it is derived as follows:

– The suffix value of cu_qp_delta_abs, suffixVal, is derived as follows:

suffixVal = coeff_abs_level_remaining[ n ] − cMax (9-16)

– The suffix bin string is specified by invoking the EGk binarization process as specified in subclause 9.3.3.3 for suffixVal with the Exp-Golomb order k set equal to cRiceParam + 1.

### 9.3.4 Decoding process flow

#### 9.3.4.1 General

Inputs to this process are all bin strings of the binarization of the requested syntax element as specified in subclause 9.3.3.

Output of this process is the value of the syntax element.

This process specifies how each bin of a bin string is parsed for each syntax element. After parsing each bin, the resulting bin string is compared to all bin strings of the binarization of the syntax element and the following applies:

– If the bin string is equal to one of the bin strings, the corresponding value of the syntax element is the output.

– Otherwise (the bin string is not equal to one of the bin strings), the next bit is parsed.

While parsing each bin, the variable binIdx is incremented by 1 starting with binIdx being set equal to 0 for the first bin.

The parsing of each bin is specified by the following two ordered steps:

1. The derivation process for ctxTable, ctxIdx, and bypassFlag as specified in subclause 9.3.4.2 is invoked with binIdx as input and ctxTable, ctxIdx, and bypassFlag as outputs.

2. The arithmetic decoding process as specified in subclause 9.3.4.3 is invoked with ctxTable, ctxIdx, and bypassFlag as inputs and the value of the bin as output.

#### 9.3.4.2 Derivation process for ctxTable, ctxIdx and bypassFlag

##### 9.3.4.2.1 General

Input to this process is the position of the current bin within the bin string, binIdx.

Outputs of this process are ctxTable, ctxIdx, and bypassFlag.

The values of ctxTable, ctxIdx, and bypassFlag are derived as follows based on the entries for binIdx of the corresponding syntax element in Table 9-37:

– If the entry in Table 9-37 is not equal to "bypass", "terminate", and "na", the values of binIdx are decoded by invoking the DecodeDecision process as specified in subclause 9.3.4.3.2 and the following applies:
  – ctxTable is specified in Table 9-4.
  – The variable ctxInc is specified by the corresponding entry in Table 9-37 and when more than one value is listed in Table 9-37 for a binIdx, the assignment process for ctxInc for that binIdx is further specified in the subclauses given in parenthesis.
  – The variable ctxIdxOffset is specified by the lowest value of ctxIdx in Table 9-4 depending on the current value of initType.
  – ctxIdx is set equal to the sum of ctxInc and ctxIdxOffset.
  – bypass Flag is set equal to 0.
– Otherwise, if the entry in Table 9-37 is equal to "bypass", the values of binIdx are decoded by invoking the DecodeBypass process as specified in subclause 9.3.4.3.4 and the following applies:
  – ctxTable is set equal to 0.
  – ctxIdx is set equal to 0.
  – bypassFlag is set equal to 1.
– Otherwise, if the entry in Table 9-37 is equal to "terminate", the values of binIdx are decoded by invoking the DecodeTerminate process as specified in subclause 9.3.4.3.5 and the following applies:
  – ctxTable is set equal to 0.
  – ctxIdx is set equal to 0.
  – bypassFlag is set equal to 0.
– Otherwise (the entry in Table 9-37 is equal to "na"), the values of binIdx do not occur for the corresponding syntax element.

**Table 9-37 – Assignment of ctxInc to syntax elements with context coded bins**

| Syntax element | binIdx | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | >= 5 |
| end_of_slice_segment_flag | terminate | na | na | na | na | na |
| end_of_sub_stream_one_bit | terminate | na | na | na | na | na |
| sao_merge_left_flag | 0 | na | na | na | na | na |
| sao_merge_up_flag | 0 | na | na | na | na | na |
| sao_type_idx_luma | 0 | bypass | na | na | na | na |
| sao_type_idx_chroma | 0 | bypass | na | na | na | na |
| sao_offset_abs[ ][ ][ ][ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| sao_offset_sign[ ][ ][ ][ ] | bypass | na | na | na | na | na |
| sao_band_position[ ][ ][ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| sao_eo_class_luma | bypass | bypass | bypass | na | na | na |
| sao_eo_class_chroma | bypass | bypass | bypass | na | na | na |
| split_cu_flag[ ][ ] | 0,1,2 (subclause 9.3.4.2.2) | na | na | na | na | na |
| cu_transquant_bypass_flag | 0 | na | na | na | na | na |
| cu_skip_flag | 0,1,2 (subclause 9.3.4.2.2) | na | na | na | na | na |
| pred_mode_flag | 0 | na | na | na | na | na |
| part_mode log2CbSize = = MinCbLog2SizeY | 0 | 1 | 2 | bypass | na | na |

**Table 9-37 – Assignment of ctxInc to syntax elements with context coded bins**

| Syntax element | binIdx | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | 4 | >= 5 |
| part_mode<br>log2CbSize > MinCbLog2SizeY | 0 | 1 | 3 | bypass | na | na |
| pcm_flag[ ][ ] | terminate | na | na | na | na | na |
| prev_intra_luma_pred_flag[ ][ ] | 0 | na | na | na | na | na |
| mpm_idx[ ][ ] | bypass | bypass | na | na | na | na |
| rem_intra_luma_pred_mode[ ][ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| intra_chroma_pred_mode[ ][ ] | 0 | bypass | bypass | na | na | na |
| rqt_root_cbf | 0 | na | na | na | na | na |
| merge_flag[ ][ ] | 0 | na | na | na | na | na |
| merge_idx[ ][ ] | 0 | bypass | bypass | bypass | na | na |
| inter_pred_idc[ x0 ][ y0 ] | ( nPbW + nPbH ) != 12<br>? CtDepth[ x0 ][ y0 ] : 4 | 4 | na | na | na | na |
| ref_idx_l0[ ][ ] | 0 | 1 | bypass | bypass | bypass | bypass |
| ref_idx_l1[ ][ ] | 0 | 1 | bypass | bypass | bypass | bypass |
| mvp_l0_flag[ ][ ] | 0 | na | na | na | na | na |
| mvp_l1_flag[ ][ ] | 0 | na | na | na | na | na |
| split_transform_flag[ ][ ][ ] | 5 − log2TrafoSize | na | na | na | na | na |
| cbf_cb[ ][ ][ ] | trafoDepth | na | na | na | na | na |
| cbf_cr[ ][ ][ ] | trafoDepth | na | na | na | na | na |
| cbf_luma[ ][ ][ ] | trafoDepth = = 0 ? 1 : 0 | na | na | na | na | na |
| abs_mvd_greater0_flag[ ] | 0 | na | na | na | na | na |
| abs_mvd_greater1_flag[ ] | 0 | na | na | na | na | na |
| abs_mvd_minus2[ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| mvd_sign_flag[ ] | bypass | na | na | na | na | na |
| cu_qp_delta_abs | 0 | 1 | 1 | 1 | 1 | bypass |
| cu_qp_delta_sign_flag | bypass | na | na | na | na | na |
| transform_skip_flag[ ][ ][ ] | 0 | na | na | na | na | na |
| last_sig_coeff_x_prefix | 0..17 (subclause 9.3.4.2.3) | | | | | |
| last_sig_coeff_y_prefix | 0..17 (subclause 9.3.4.2.3) | | | | | |
| last_sig_coeff_x_suffix | bypass | bypass | bypass | bypass | bypass | bypass |
| last_sig_coeff_y_suffix | bypass | bypass | bypass | bypass | bypass | bypass |
| coded_sub_block_flag[ ][ ] | 0..3<br>(subclause 9.3.4.2.4) | na | na | na | na | na |
| sig_coeff_flag[ ][ ] | 0..41<br>(subclause 9.3.4.2.5) | na | na | na | na | na |
| coeff_abs_level_greater1_flag[ ] | 0..23<br>(subclause 9.3.4.2.6) | na | na | na | na | na |
| coeff_abs_level_greater2_flag[ ] | 0..5<br>(subclause 9.3.4.2.7) | na | na | na | na | na |
| coeff_abs_level_remaining[ ] | bypass | bypass | bypass | bypass | bypass | bypass |
| coeff_sign_flag[ ] | bypass | na | na | na | na | na |

### 9.3.4.2.2 Derivation process of ctxInc using left and above syntax elements

Input to this process is the luma location ( x0, y0 ) specifying the top-left luma sample of the current luma block relative to the top-left sample of the current picture.

Output of this process is ctxInc.

The location ( xNbL, yNbL ) is set equal to ( x0 − 1, y0 ) and the variable availableL, specifying the availability of the block located directly to the left of the current block, is derived by invoking the availability derivation process for a block in z-scan order as specified in subclause 6.4.1 with the location ( xCurr, yCurr ) set equal to ( x0, y0 ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xNbL, yNbL ) as inputs, and the output is assigned to availableL.

The location ( xNbA, yNbA ) is set equal to ( x0, y0 − 1 ) and the variable availableA specifying the availability of the coding block located directly above the current block, is derived by invoking the availability derivation process for a block in z-scan order as specified in subclause 6.4.1 with the location ( xCurr, yCurr ) set equal to ( x0, y0 ) and the neighbouring location ( xNbY, yNbY ) set equal to ( xNbA, yNbA ) as inputs, and the output is assigned to availableA.

The assignment of ctxInc for the syntax elements split_cu_flag[ x0 ][ y0 ] and cu_skip_flag[ x0 ][ y0 ] is specified in Table 9-38.

**Table 9-38 – Specification of ctxInc using left and above syntax elements**

| Syntax element | condL | condA | ctxInc |
|---|---|---|---|
| split_cu_flag[ x0 ][ y0 ] | CtDepth[ xNbL ][ yNbL ] > cqtDepth | CtDepth[ xNbA ][ yNbA ] > cqtDepth | ( condL && availableL ) + ( condA && availableA ) |
| cu_skip_flag[ x0 ][ y0 ] | cu_skip_flag[ xNbL ][ yNbL ] | cu_skip_flag[ xNbA ][ yNbA ] | ( condL && availableL ) + ( condA && availableA ) |

### 9.3.4.2.3 Derivation process of ctxInc for the syntax elements last_sig_coeff_x_prefix and last_sig_coeff_y_prefix

Inputs to this process are the variable binIdx, the colour component index cIdx, and the transform block size log2TrafoSize.

Output of this process is the variable ctxInc.

The variables ctxOffset and ctxShift are derived as follows:

– If cIdx is equal to 0, ctxOffset is set equal to 3 * ( log2TrafoSize − 2 ) + ( ( log2TrafoSize − 1 ) >> 2 ) and ctxShift is set equal to ( log2TrafoSize + 1 ) >> 2.

– Otherwise (cIdx is greater than 0), ctxOffset is set equal to 15 and ctxShift is set equal to log2TrafoSize − 2.

The variable ctxInc is derived as follows:

ctxInc = ( binIdx >> ctxShift ) + ctxOffset (9-17)

### 9.3.4.2.4 Derivation process of ctxInc for the syntax element coded_sub_block_flag

Inputs to this process are the colour component index cIdx, the current sub-block scan location ( xS, yS ), the previously decoded bins of the syntax element coded_sub_block_flag, and the transform block size log2TrafoSize.

Output of this process is the variable ctxInc.

The variable csbfCtx is derived using the current location ( xS, yS ), two previously decoded bins of the syntax element coded_sub_block_flag in scan order, and the transform block size log2TrafoSize, as follows:

– csbfCtx is initialized with 0 as follows:

csbfCtx = 0 (9-18)

– When xS is less than ( 1 << ( log2TrafoSize − 2 ) ) − 1, csbfCtx is modified as follows:

csbfCtx += coded_sub_block_flag[ xS + 1 ][ yS ] (9-19)

– When yS is less than ( 1 << ( log2TrafoSize − 2 ) ) − 1, csbfCtx is modified as follows:

csbfCtx += coded_sub_block_flag[ xS ][ yS + 1 ] (9-20)

The context index increment ctxInc is derived using the colour component index cIdx and csbfCtx as follows:

– If cIdx is equal to 0, ctxInc is derived as follows:

$$ctxInc = Min( csbfCtx, 1 ) \qquad (9\text{-}21)$$

– Otherwise (cIdx is greater than 0), ctxInc is derived as follows:

$$ctxInc = 2 + Min( csbfCtx, 1 ) \qquad (9\text{-}22)$$

### 9.3.4.2.5 Derivation process of ctxInc for the syntax element sig_coeff_flag

Inputs to this process are the colour component index cIdx, the current coefficient scan location ( xC, yC ), the scan order index scanIdx, and the transform block size log2TrafoSize.

Output of this process is the variable ctxInc.

The variable sigCtx depends on the current location ( xC, yC ), the colour component index cIdx, the transform block size, and previously decoded bins of the syntax element coded_sub_block_flag. For the derivation of sigCtx, the following applies:

– If log2TrafoSize is equal to 2, sigCtx is derived using ctxIdxMap[ ] specified in Table 9-39 as follows:

$$sigCtx = ctxIdxMap[ ( yC << 2 ) + xC ] \qquad (9\text{-}23)$$

– Otherwise, if xC + yC is equal to 0, sigCtx is derived as follows:

$$sigCtx = 0 \qquad (9\text{-}24)$$

– Otherwise, sigCtx is derived using previous values of coded_sub_block_flag as follows:
  – The sub-block location ( xS, yS ) is set equal to ( xC >> 2, yC >> 2 ).
  – The variable prevCsbf is set equal to 0.
  – When xS is less than ( 1 << ( log2TrafoSize − 2 ) ) − 1, the following applies:

$$prevCsbf \mathrel{+}= coded\_sub\_block\_flag[ xS + 1 ][ yS ] \qquad (9\text{-}25)$$

  – When yS is less than ( 1 << ( log2TrafoSize − 2 ) ) − 1, the following applies:

$$prevCsbf \mathrel{+}= ( coded\_sub\_block\_flag[ xS ][ yS + 1 ] << 1 ) \qquad (9\text{-}26)$$

  – The inner sub-block location ( xP, yP ) is set equal to ( xC & 3, yC & 3 ).
  – The variable sigCtx is derived as follows:
    – If prevCsbf is equal to 0, the following applies:

$$sigCtx = ( xP + yP == 0 ) ? 2 : ( xP + yP < 3 ) ? 1: 0 \qquad (9\text{-}27)$$

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

$$sigCtx = ( yP == 0 ) ? 2 : ( yP == 1 ) ? 1: 0 \qquad (9\text{-}28)$$

    – Otherwise, if prevCsbf is equal to 2, the following applies:

$$sigCtx = ( xP == 0 ) ? 2 : ( xP == 1 ) ? 1: 0 \qquad (9\text{-}29)$$

    – Otherwise (prevCsbf is equal to 3), the following applies:

$$sigCtx = 2 \qquad (9\text{-}30)$$

  – The variable sigCtx is modified as follows:
    – If cIdx is equal to 0, the following applies:
      – When ( xS + yS ) is greater than 0, the following applies:

$$sigCtx \mathrel{+}= 3 \qquad (9\text{-}31)$$

      – The variable sigCtx is modified as follows:
        – If log2TrafoSize is equal to 3, the following applies:

$$sigCtx \mathrel{+}= ( scanIdx == 0 ) ? 9 : 15 \qquad (9\text{-}32)$$

– Otherwise, the following applies:

sigCtx += 21 (9-33)

– Otherwise (cIdx is greater than 0), the following applies:

– If log2TrafoSize is equal to 3, the following applies:

sigCtx += 9 (9-34)

– Otherwise, the following applies:

sigCtx += 12 (9-35)

The context index increment ctxInc is derived using the colour component index cIdx and sigCtx as follows:

– If cIdx is equal to 0, ctxInc is derived as follows:

ctxInc = sigCtx (9-36)

– Otherwise (cIdx is greater than 0), ctxInc is derived as follows:

ctxInc = 27 + sigCtx (9-37)

**Table 9-39 – Specification of ctxIdxMap[ i ]**

| **i** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ctxIdxMap[ i ]** | 0 | 1 | 4 | 5 | 2 | 3 | 4 | 5 | 6 | 6 | 8 | 8 | 7 | 7 | 8 |

### 9.3.4.2.6 Derivation process of ctxInc for the syntax element coeff_abs_level_greater1_flag

Inputs to this process are the colour component index cIdx, the current sub-block scan index i, and the current coefficient scan index n within the current sub-block.

Output of this process is the variable ctxInc.

The variable ctxSet specifies the current context set and for its derivation the following applies:

– If this process is invoked for the first time for the current sub-block scan index i, the following applies:

– The variable ctxSet is initialized as follows:

– If the current sub-block scan index i is equal to 0 or cIdx is greater than 0, the following applies:

ctxSet = 0 (9-38)

– Otherwise (i is greater than 0 and cIdx is equal to 0), the following applies:

ctxSet = 2 (9-39)

– The variable lastGreater1Ctx is derived as follows:

– If the current sub-block with scan index i is the first one to be processed in this subclause for the current transform block, the variable lastGreater1Ctx is set equal to 1.

– Otherwise, the following applies:

– The variable lastGreater1Ctx is set equal to the value of greater1Ctx that has been derived during the last invocation of the process specified in this subclause for a previous sub-block.

– When lastGreater1Ctx is greater than 0, the variable lastGreater1Flag is set equal to the value of the syntax element coeff_abs_level_greater1_flag that has been used during the last invocation of the process specified in this subclause for a previous sub-block and lastGreater1Ctx is modified as follows:

– If lastGreater1Flag is equal to 1, lastGreater1Ctx is set equal to 0.

– Otherwise (lastGreater1Flag is equal to 0), lastGreater1Ctx is incremented by 1.

– When lastGreater1Ctx is equal to 0, ctxSet is incremented by one as follows:

ctxSet = ctxSet + 1 (9-40)

– The variable greater1Ctx is set equal to 1.

– Otherwise (this process is not invoked for the first time for the current sub-block scan index i), the following applies:
  – The variable ctxSet is set equal to the variable ctxSet that has been derived during the last invocation of the process specified in this subclause.
  – The variable greater1Ctx is set equal to the variable greater1Ctx that has been derived during the last invocation of the process specified in this subclause.
  – When greater1Ctx is greater than 0, the variable lastGreater1Flag is set equal to the syntax element coeff_abs_level_greater1_flag that has been used during the last invocation of the process specified in this subclause and greater1Ctx is modified as follows:
    – If lastGreater1Flag is equal to 1, greater1Ctx is set equal to 0.
    – Otherwise (lastGreater1Flag is equal to 0), greater1Ctx is incremented by 1.

The context index increment ctxInc is derived using the current context set ctxSet and the current context greater1Ctx as follows:

$$\text{ctxInc} = (\ \text{ctxSet} * 4\ ) + \text{Min}(\ 3, \text{greater1Ctx}\ ) \tag{9-41}$$

When cIdx is greater than 0, ctxInc is modified as follows:

$$\text{ctxInc} = \text{ctxInc} + 16 \tag{9-42}$$

#### 9.3.4.2.7 Derivation process of ctxInc for the syntax element coeff_abs_level_greater2_flag

Inputs to this process are the colour component index cIdx, the current sub-block scan index i, and the current coefficient scan index n within the current sub-block.

Output of this process is the variable ctxInc.

The variable ctxSet specifies the current context set and is set equal to the value of the variable ctxSet that has been derived in subclause 9.3.4.2.6 for the same subset i.

The context index increment ctxInc is set equal to the variable ctxSet as follows:

$$\text{ctxInc} = \text{ctxSet} \tag{9-43}$$

When cIdx is greater than 0, ctxInc is modified as follows:

$$\text{ctxInc} = \text{ctxInc} + 4 \tag{9-44}$$

### 9.3.4.3 Arithmetic decoding process

#### 9.3.4.3.1 General

Inputs to this process are ctxTable, ctxIdx, and bypassFlag, as derived in subclause 9.3.4.2, and the state variables ivlCurrRange and ivlOffset of the arithmetic decoding engine.

Output of this process is the value of the bin.

Figure 9-5 illustrates the whole arithmetic decoding process for a single bin. For decoding the value of a bin, the context index table ctxTable and the ctxIdx are passed to the arithmetic decoding process DecodeBin( ctxTable, ctxIdx ), which is specified as follows:

– If bypassFlag is equal to 1, DecodeBypass( ) as specified in subclause 9.3.4.3.4 is invoked.
– Otherwise, if bypassFlag is equal to 0, ctxTable is equal to 0, and ctxIdx is equal to 0, DecodeTerminate( ) as specified in subclause 9.3.4.3.5 is invoked.
– Otherwise (bypassFlag is equal to 0 and ctxTable is not equal to 0), DecodeDecision( ) as specified in subclause 9.3.4.3.2 is invoked.

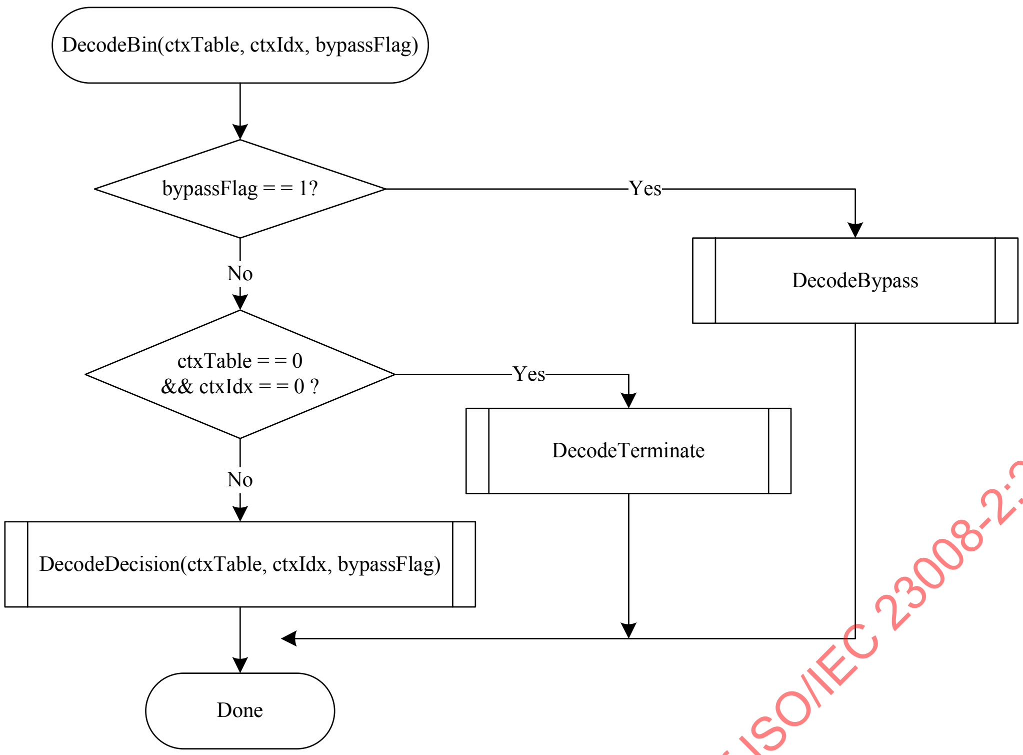


**Figure 9-5 – Overview of the arithmetic decoding process for a single bin (informative)**

NOTE – Arithmetic coding is based on the principle of recursive interval subdivision. Given a probability estimation p( 0 ) and p( 1 ) = 1 – p( 0 ) of a binary decision ( 0, 1 ), an initially given code sub-interval with the range ivlCurrRange will be subdivided into two sub-intervals having range p( 0 ) * ivlCurrRange and ivlCurrRange – p( 0 ) * ivlCurrRange, respectively. Depending on the decision, which has been observed, the corresponding sub-interval will be chosen as the new code interval, and a binary code string pointing into that interval will represent the sequence of observed binary decisions. It is useful to distinguish between the most probable symbol (MPS) and the least probable symbol (LPS), so that binary decisions have to be identified as either MPS or LPS, rather than 0 or 1. Given this terminology, each context is specified by the probability $p_{LPS}$ of the LPS and the value of MPS (valMps), which is either 0 or 1. The arithmetic core engine in this Specification has three distinct properties:

– The probability estimation is performed by means of a finite-state machine with a table-based transition process between 64 different representative probability states { $p_{LPS}$( pStateIdx ) | 0 <= pStateIdx < 64 } for the LPS probability $p_{LPS}$. The numbering of the states is arranged in such a way that the probability state with index pStateIdx = 0 corresponds to an LPS probability value of 0.5, with decreasing LPS probability towards higher state indices.

– The range ivlCurrRange representing the state of the coding engine is quantized to a small set {$Q_1,\ldots,Q_4$} of pre-set quantization values prior to the calculation of the new interval range. Storing a table containing all 64x4 pre-computed product values of $Q_i$ * $p_{LPS}$( pStateIdx ) allows a multiplication-free approximation of the product ivlCurrRange * $p_{LPS}$( pStateIdx ).

– For syntax elements or parts thereof for which an approximately uniform probability distribution is assumed to be given a separate simplified encoding and decoding bypass process is used.

### 9.3.4.3.2 Arithmetic decoding process for a binary decision

#### 9.3.4.3.2.1 General

Inputs to this process are the variables ctxTable, ctxIdx, ivlCurrRange, and ivlOffset.

Outputs of this process are the decoded value binVal, and the updated variables ivlCurrRange and ivlOffset.

Figure 9-6 shows the flowchart for decoding a single decision (DecodeDecision):

1. The value of the variable ivlLpsRange is derived as follows:

   – Given the current value of ivlCurrRange, the variable qRangeIdx is derived as follows:

     qRangeIdx =( ivlCurrRange >> 6 ) & 3 (9-45)

   – Given qRangeIdx and pStateIdx associated with ctxTable and ctxIdx, the value of the variable rangeTabLps as specified in Table 9-40 is assigned to ivlLpsRange:

     ivlLpsRange = rangeTabLps[ pStateIdx ][ qRangeIdx ] (9-46)

2. The variable ivlCurrRange is set equal to ivlCurrRange − ivlLpsRange and the following applies:

   – If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1 − valMps, ivlOffset is decremented by ivlCurrRange, and ivlCurrRange is set equal to ivlLpsRange.

   – Otherwise, the variable binVal is set equal to valMps.

Given the value of binVal, the state transition is performed as specified in subclause 9.3.4.3.2.2. Depending on the current value of ivlCurrRange, renormalization is performed as specified in subclause 9.3.4.3.3.

#### 9.3.4.3.2.2 State transition process

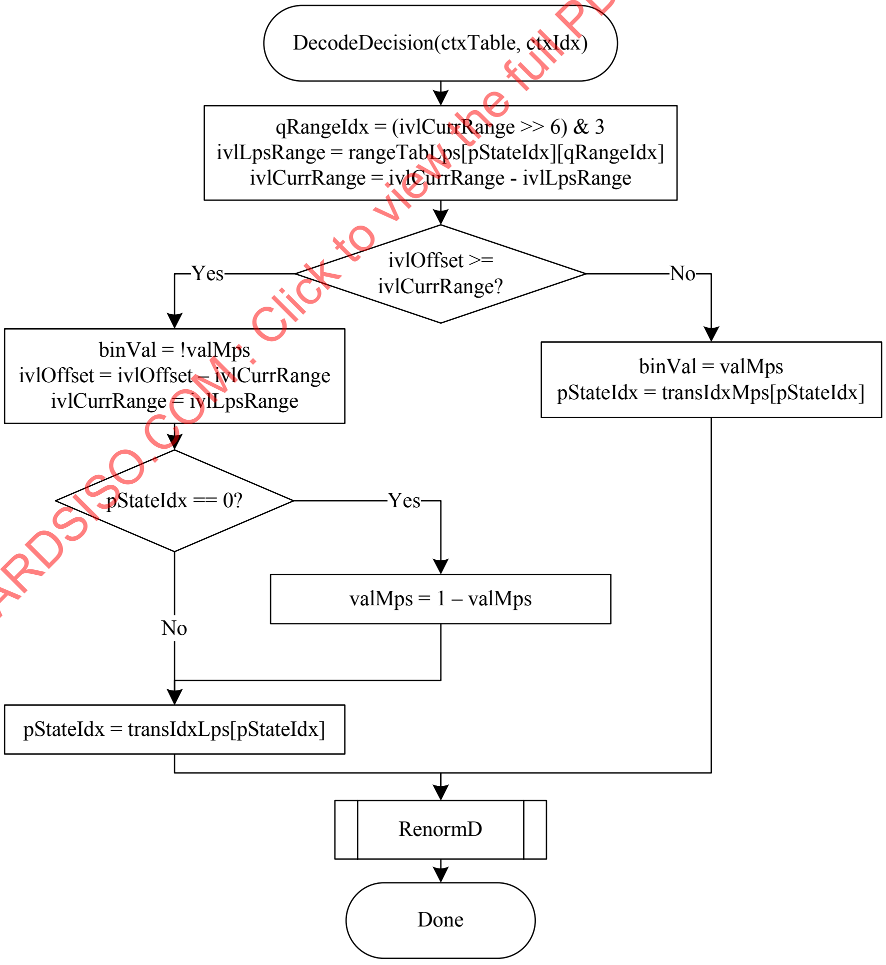
Inputs to this process are the current pStateIdx, the decoded value binVal and valMps values of the context variable associated with ctxTable and ctxIdx.

Outputs of this process are the updated pStateIdx and valMps of the context variable associated with ctxIdx.

Depending on the decoded value binVal, the update of the two variables pStateIdx and valMps associated with ctxIdx is derived as follows:

```
if( binVal  = =  valMps )
    pStateIdx = transIdxMps( pStateIdx )
else {                                                          (9-47)
    if( pStateIdx  = =  0 )
        valMps = 1 − valMps
    pStateIdx = transIdxLps( pStateIdx )
}
```

Table 9-41 specifies the transition rules transIdxMps( ) and transIdxLps( ) after decoding the value of valMps and 1 − valMps, respectively.



DecodeDecision(ctxTable, ctxIdx)
qRangeIdx = (ivlCurrRange >> 6) & 3
ivlLpsRange = rangeTabLps[pStateIdx][qRangeIdx]
ivlCurrRange = ivlCurrRange - ivlLpsRange
ivlOffset >= ivlCurrRange?
Yes
No
binVal = !valMps
ivlOffset = ivlOffset – ivlCurrRange
ivlCurrRange = ivlLpsRange
binVal = valMps
pStateIdx = transIdxMps[pStateIdx]
pStateIdx == 0?
Yes
valMps = 1 – valMps
No
pStateIdx = transIdxLps[pStateIdx]
RenormD
Done

**Figure 9-6 – Flowchart for decoding a decision**

**Table 9-40 – Specification of rangeTabLps depending on the values of pStateIdx and qRangeIdx**

| pStateIdx | qRangeIdx | | | | pStateIdx | qRangeIdx | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | 1 | 2 | 3 | | 0 | 1 | 2 | 3 |
| 0 | 128 | 176 | 208 | 240 | 32 | 27 | 33 | 39 | 45 |
| 1 | 128 | 167 | 197 | 227 | 33 | 26 | 31 | 37 | 43 |
| 2 | 128 | 158 | 187 | 216 | 34 | 24 | 30 | 35 | 41 |
| 3 | 123 | 150 | 178 | 205 | 35 | 23 | 28 | 33 | 39 |
| 4 | 116 | 142 | 169 | 195 | 36 | 22 | 27 | 32 | 37 |
| 5 | 111 | 135 | 160 | 185 | 37 | 21 | 26 | 30 | 35 |
| 6 | 105 | 128 | 152 | 175 | 38 | 20 | 24 | 29 | 33 |
| 7 | 100 | 122 | 144 | 166 | 39 | 19 | 23 | 27 | 31 |
| 8 | 95 | 116 | 137 | 158 | 40 | 18 | 22 | 26 | 30 |
| 9 | 90 | 110 | 130 | 150 | 41 | 17 | 21 | 25 | 28 |
| 10 | 85 | 104 | 123 | 142 | 42 | 16 | 20 | 23 | 27 |
| 11 | 81 | 99 | 117 | 135 | 43 | 15 | 19 | 22 | 25 |
| 12 | 77 | 94 | 111 | 128 | 44 | 14 | 18 | 21 | 24 |
| 13 | 73 | 89 | 105 | 122 | 45 | 14 | 17 | 20 | 23 |
| 14 | 69 | 85 | 100 | 116 | 46 | 13 | 16 | 19 | 22 |
| 15 | 66 | 80 | 95 | 110 | 47 | 12 | 15 | 18 | 21 |
| 16 | 62 | 76 | 90 | 104 | 48 | 12 | 14 | 17 | 20 |
| 17 | 59 | 72 | 86 | 99 | 49 | 11 | 14 | 16 | 19 |
| 18 | 56 | 69 | 81 | 94 | 50 | 11 | 13 | 15 | 18 |
| 19 | 53 | 65 | 77 | 89 | 51 | 10 | 12 | 15 | 17 |
| 20 | 51 | 62 | 73 | 85 | 52 | 10 | 12 | 14 | 16 |
| 21 | 48 | 59 | 69 | 80 | 53 | 9 | 11 | 13 | 15 |
| 22 | 46 | 56 | 66 | 76 | 54 | 9 | 11 | 12 | 14 |
| 23 | 43 | 53 | 63 | 72 | 55 | 8 | 10 | 12 | 14 |
| 24 | 41 | 50 | 59 | 69 | 56 | 8 | 9 | 11 | 13 |
| 25 | 39 | 48 | 56 | 65 | 57 | 7 | 9 | 11 | 12 |
| 26 | 37 | 45 | 54 | 62 | 58 | 7 | 9 | 10 | 12 |
| 27 | 35 | 43 | 51 | 59 | 59 | 7 | 8 | 10 | 11 |
| 28 | 33 | 41 | 48 | 56 | 60 | 6 | 8 | 9 | 11 |
| 29 | 32 | 39 | 46 | 53 | 61 | 6 | 7 | 9 | 10 |
| 30 | 30 | 37 | 43 | 50 | 62 | 6 | 7 | 8 | 9 |
| 31 | 29 | 35 | 41 | 48 | 63 | 2 | 2 | 2 | 2 |

**Table 9-41 – State transition table**

| **pStateIdx** | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **transIdxLps** | 0 | 0 | 1 | 2 | 2 | 4 | 4 | 5 | 6 | 7 | 8 | 9 | 9 | 11 | 11 | 12 |
| **transIdxMps** | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
| **pStateIdx** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **26** | **27** | **28** | **29** | **30** | **31** |
| **transIdxLps** | 13 | 13 | 15 | 15 | 16 | 16 | 18 | 18 | 19 | 19 | 21 | 21 | 22 | 22 | 23 | 24 |
| **transIdxMps** | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 |
| **pStateIdx** | **32** | **33** | **34** | **35** | **36** | **37** | **38** | **39** | **40** | **41** | **42** | **43** | **44** | **45** | **46** | **47** |
| **transIdxLps** | 24 | 25 | 26 | 26 | 27 | 27 | 28 | 29 | 29 | 30 | 30 | 30 | 31 | 32 | 32 | 33 |
| **transIdxMps** | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 |
| **pStateIdx** | **48** | **49** | **50** | **51** | **52** | **53** | **54** | **55** | **56** | **57** | **58** | **59** | **60** | **61** | **62** | **63** |
| **transIdxLps** | 33 | 33 | 34 | 34 | 35 | 35 | 35 | 36 | 36 | 36 | 37 | 37 | 37 | 38 | 38 | 63 |
| **transIdxMps** | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 62 | 63 |

### 9.3.4.3.3 Renormalization process in the arithmetic decoding engine

Inputs to this process are bits from slice segment data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variables ivlCurrRange and ivlOffset.

A flowchart of the renormalization is shown in Figure 9-7. The current value of ivlCurrRange is first compared to 256 and further steps are specified as follows:

– If ivlCurrRange is greater than or equal to 256, no renormalization is needed and the RenormD process is finished;

– Otherwise (ivlCurrRange is less than 256), the renormalization loop is entered. Within this loop, the value of ivlCurrRange is doubled, i.e. left-shifted by 1 and a single bit is shifted into ivlOffset by using read_bits( 1 ).

The bitstream shall not contain data that result in a value of ivlOffset being greater than or equal to ivlCurrRange upon completion of this process.

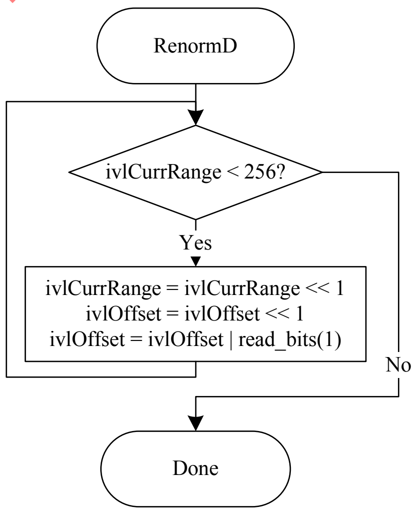

RenormD
ivlCurrRange < 256?
Yes
ivlCurrRange = ivlCurrRange << 1
ivlOffset = ivlOffset << 1
ivlOffset = ivlOffset | read_bits(1)
No
Done

**Figure 9-7 – Flowchart of renormalization**

### 9.3.4.3.4 Bypass decoding process for binary decisions

Inputs to this process are bits from slice segment data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variable ivlOffset and the decoded value binVal.

The bypass decoding process is invoked when bypassFlag is equal to 1. Figure 9-8 shows a flowchart of the corresponding process.

First, the value of ivlOffset is doubled, i.e. left-shifted by 1 and a single bit is shifted into ivlOffset by using read_bits( 1 ). Then, the value of ivlOffset is compared to the value of ivlCurrRange and further steps are specified as follows:

– If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1 and ivlOffset is decremented by ivlCurrRange.

– Otherwise (ivlOffset is less than ivlCurrRange), the variable binVal is set equal to 0.

The bitstream shall not contain data that result in a value of ivlOffset being greater than or equal to ivlCurrRange upon completion of this process.

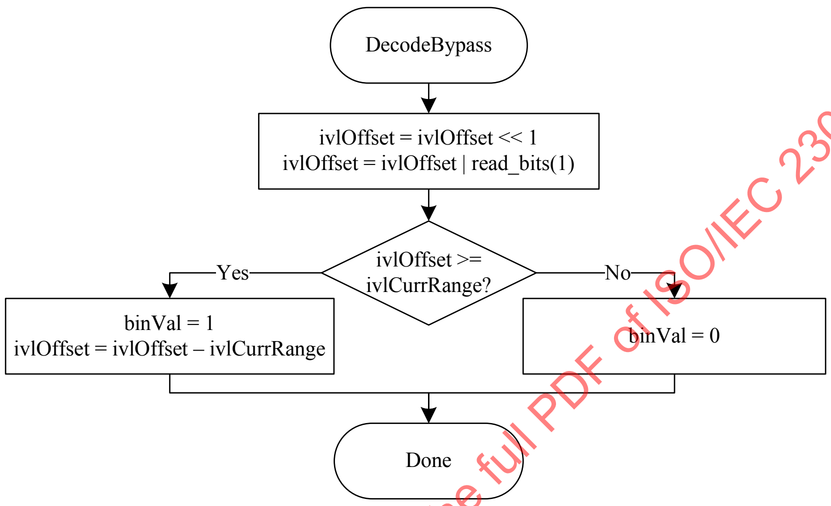

DecodeBypass
ivlOffset = ivlOffset << 1
ivlOffset = ivlOffset | read_bits(1)
ivlOffset >=
ivlCurrRange?
Yes
No
binVal = 1
ivlOffset = ivlOffset – ivlCurrRange
binVal = 0
Done

**Figure 9-8 – Flowchart of bypass decoding process**

### 9.3.4.3.5 Decoding process for binary decisions before termination

Inputs to this process are bits from slice segment data and the variables ivlCurrRange and ivlOffset.

Outputs of this process are the updated variables ivlCurrRange and ivlOffset, and the decoded value binVal.

This decoding process applies to decoding of end_of_slice_segment_flag, end_of_sub_stream_one_bit and pcm_flag corresponding to ctxTable equal to 0 and ctxIdx equal to 0. Figure 9-9 shows the flowchart of the corresponding decoding process, which is specified as follows:

First, the value of ivlCurrRange is decremented by 2. Then, the value of ivlOffset is compared to the value of ivlCurrRange and further steps are specified as follows:

– If ivlOffset is greater than or equal to ivlCurrRange, the variable binVal is set equal to 1, no renormalization is carried out, and CABAC decoding is terminated. The last bit inserted in register ivlOffset is equal to 1. When decoding end_of_slice_segment_flag, this last bit inserted in register ivlOffset is interpreted as rbsp_stop_one_bit. When decoding end_of_sub_stream_one_bit, this last bit inserted in register ivlOffset is interpreted as alignment_bit_equal_to_one.

– Otherwise (ivlOffset is less than ivlCurrRange), the variable binVal is set equal to 0 and renormalization is performed as specified in subclause 9.3.4.3.3.

NOTE – This procedure may also be implemented using DecodeDecision( ctxTable, ctxIdx, bypassFlag ) with ctxTable = 0, ctxIdx = 0 and bypassFlag = 0. In the case where the decoded value is equal to 1, seven more bits would be read by DecodeDecision( ctxTable, ctxIdx, bypassFlag ) and a decoding process would have to adjust its bitstream pointer accordingly to properly decode following syntax elements.

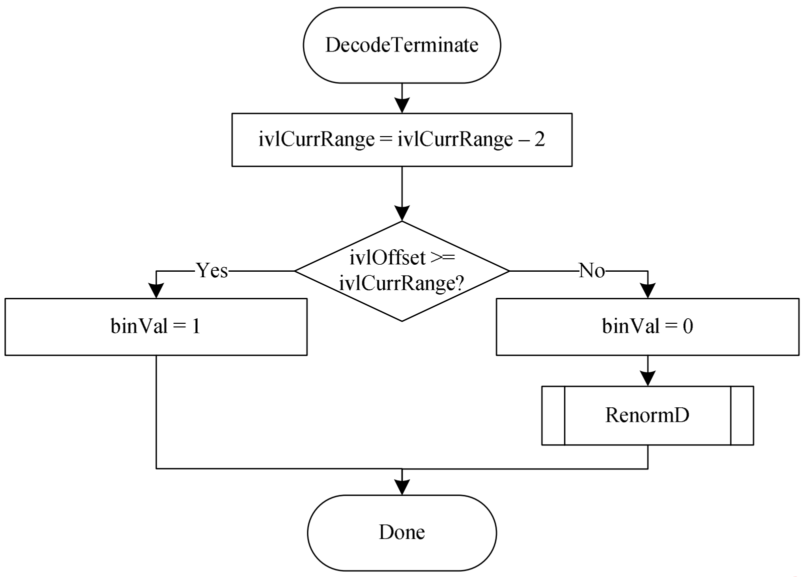


**Figure 9-9 – Flowchart of decoding a decision before termination**

### 9.3.5 Arithmetic encoding process (informative)

#### 9.3.5.1 General

This subclause does not form an integral part of this Specification.

Inputs to this process are decisions that are to be encoded and written.

Outputs of this process are bits that are written to the RBSP.

This informative subclause describes an arithmetic encoding engine that matches the arithmetic decoding engine described in subclause 9.3.4.3. The encoding engine is essentially symmetric with the decoding engine, i.e. procedures are called in the same order. The following procedures are described in this subclause: InitEncoder, EncodeDecision, EncodeBypass, EncodeTerminate, which correspond to InitDecoder, DecodeDecision, DecodeBypass, and DecodeTerminate, respectively. The state of the arithmetic encoding engine is represented by a value of the variable ivlLow pointing to the lower end of a sub-interval and a value of the variable ivlCurrRange specifying the corresponding range of that sub-interval.

#### 9.3.5.2 Initialization process for the arithmetic encoding engine (informative)

This subclause does not form an integral part of this Specification.

This process is invoked before encoding the first coding block of a slice segment, and after encoding any pcm_alignment_zero_bit and all pcm_sample_luma and pcm_sample_chroma data for a coding unit with pcm_flag equal to 1.

Outputs of this process are the values ivlLow, ivlCurrRange, firstBitFlag, bitsOutstanding, and BinCountsInNalUnits of the arithmetic encoding engine.

In the initialization procedure of the encoder, ivlLow is set equal to 0, and ivlCurrRange is set equal to 510. Furthermore, firstBitFlag is set equal to 1 and the counter bitsOutstanding is set equal to 0.

Depending on whether the current slice segment is the first slice segment of a coded picture, the following applies:

– If the current slice segment is the first slice segment of a coded picture, the counter BinCountsInNalUnits is set equal to 0.

– Otherwise (the current slice segment is not the first slice segment of a coded picture), the counter BinCountsInNalUnits is not modified. The value of BinCountsInNalUnits is the result of encoding all the slice segments of a coded picture that precede the current slice segment in decoding order. After initializing for the first slice segment of a coded picture as specified in this subclause, BinCountsInNalUnits is incremented as specified in subclauses 9.3.5.3, 9.3.5.5, and 9.3.5.6.

NOTE – The minimum register precision required for storing the values of the variables ivlLow and ivlCurrRange after invocation of any of the arithmetic encoding processes specified in subclauses 9.3.5.3, 9.3.5.5, and 9.3.5.6 is 10 bits and 9 bits, respectively. The encoding process for a binary decision (EncodeDecision) as specified in subclause 9.3.5.3 and the encoding process for a binary decision before termination (EncodeTerminate) as specified in subclause 9.3.5.6 require a minimum register precision of 10 bits for the variable ivlLow and a minimum register precision of 9 bits for the variable ivlCurrRange. The bypass encoding process for binary decisions (EncodeBypass) as specified in subclause 9.3.5.5 requires a minimum register precision of 11 bits for the variable ivlLow and a minimum register precision of 9 bits for the variable ivlCurrRange. The precision required for the counters bitsOutstanding and BinCountsInNalUnits should be sufficiently large to prevent overflow of the related registers. When maxBinCountInSlice denotes the maximum total number of binary decisions to encode in one slice segment and maxBinCountInPic denotes the maximum total number of binary decisions to encode a picture, the minimum register precision required for the variables bitsOutstanding and BinCountsInNalUnits is given by Ceil( Log2( maxBinCountInSlice + 1 ) ) and Ceil( Log2( maxBinCountInPic + 1 ) ), respectively.

### 9.3.5.3 Encoding process for a binary decision (informative)

This subclause does not form an integral part of this Specification.

Inputs to this process are the context index ctxIdx, the value of binVal to be encoded, and the variables ivlCurrRange, ivlLow and BinCountsInNalUnits.

Outputs of this process are the variables ivlCurrRange, ivlLow, and BinCountsInNalUnits.

Figure 9-10 shows the flowchart for encoding a single decision. In a first step, the variable ivlLpsRange is derived as follows:

Given the current value of ivlCurrRange, ivlCurrRange is mapped to the index qRangeIdx of a quantized value of ivlCurrRange by using Equation 9-45. The value of qRangeIdx and the value of pStateIdx associated with ctxIdx are used to determine the value of the variable rangeTabLps as specified in Table 9-40, which is assigned to ivlLpsRange. The value of ivlCurrRange − ivlLpsRange is assigned to ivlCurrRange.

In a second step, the value of binVal is compared to valMps associated with ctxIdx. When binVal is different from valMps, ivlCurrRange is added to ivlLow and ivlCurrRange is set equal to the value ivlLpsRange. Given the encoded decision, the state transition is performed as specified in subclause 9.3.4.3.2.2. Depending on the current value of ivlCurrRange, renormalization is performed as specified in subclause 9.3.5.4. Finally, the variable BinCountsInNalUnits is incremented by 1.

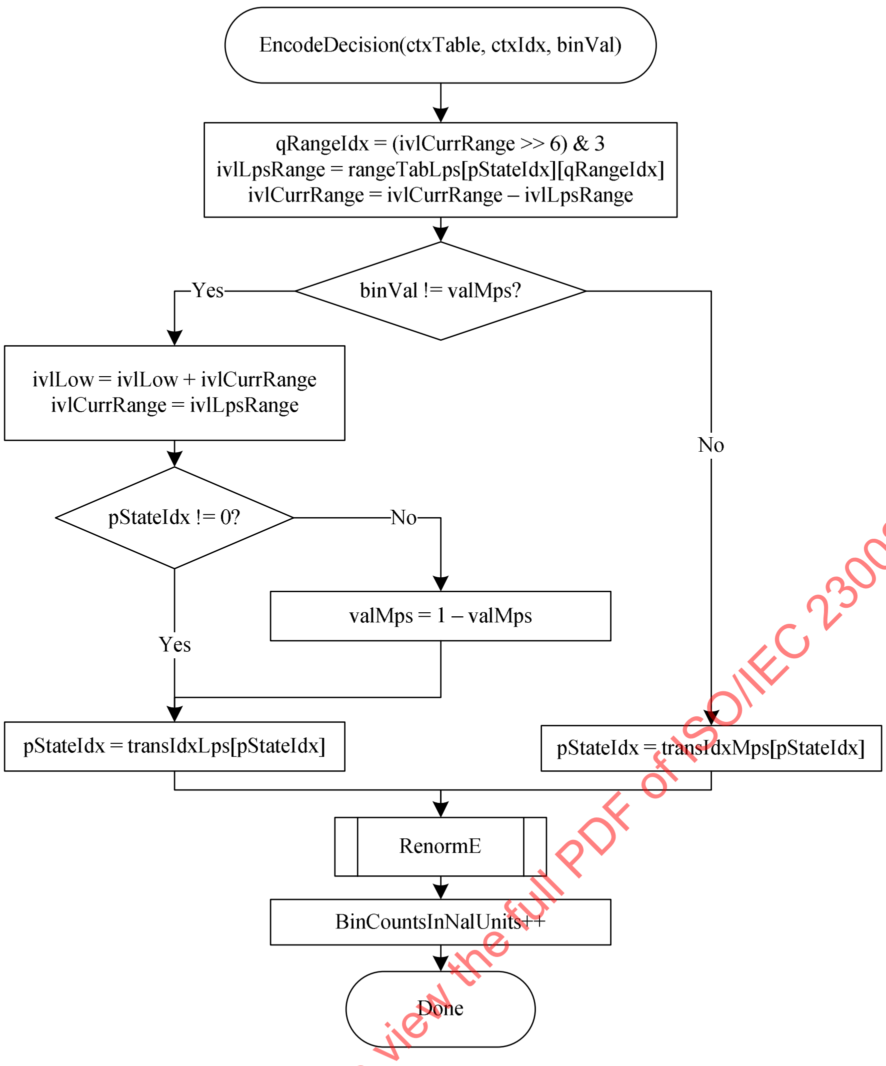

EncodeDecision(ctxTable, ctxIdx, binVal)
qRangeIdx = (ivlCurrRange >> 6) & 3
ivlLpsRange = rangeTabLps[pStateIdx][qRangeIdx]
ivlCurrRange = ivlCurrRange – ivlLpsRange
binVal != valMps?
Yes
No
ivlLow = ivlLow + ivlCurrRange
ivlCurrRange = ivlLpsRange
pStateIdx != 0?
No
Yes
valMps = 1 – valMps
pStateIdx = transIdxLps[pStateIdx]
pStateIdx = transIdxMps[pStateIdx]
RenormE
BinCountsInNalUnits++
Done

**Figure 9-10 – Flowchart for encoding a decision**

### 9.3.5.4 Renormalization process in the arithmetic encoding engine (informative)

This subclause does not form an integral part of this Specification.

Inputs to this process are the variables ivlCurrRange, ivlLow, firstBitFlag, and bitsOutstanding.

Outputs of this process are zero or more bits written to the RBSP and the updated variables ivlCurrRange, ivlLow, firstBitFlag, and bitsOutstanding.

Renormalization is illustrated in Figure 9-11.

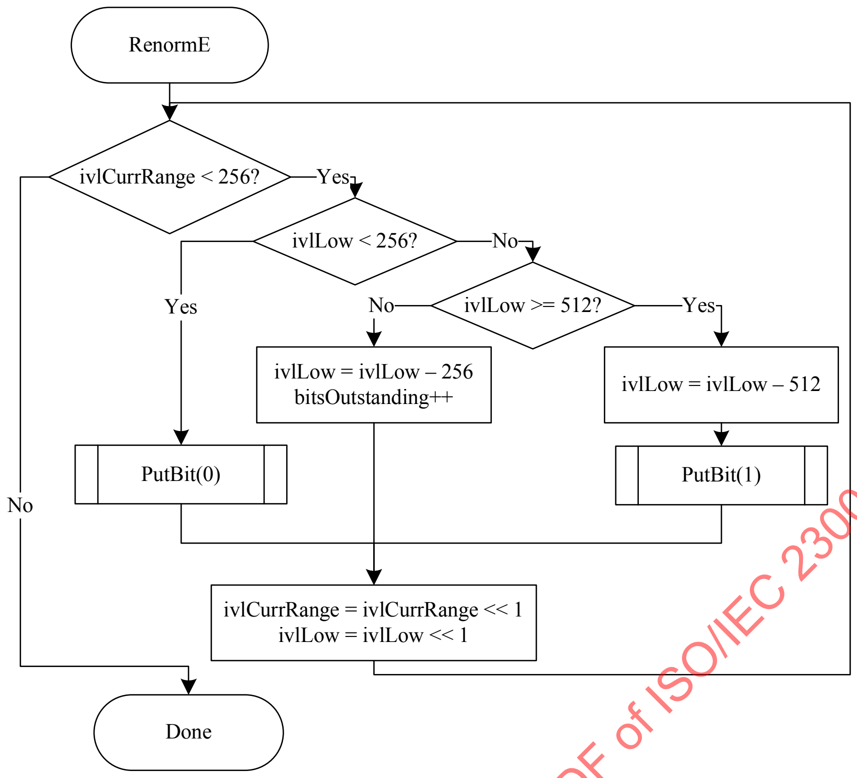


**Figure 9-11 – Flowchart of renormalization in the encoder**

The PutBit( ) procedure described in Figure 9-12 provides carry over control. It uses the function WriteBits( B, N ) that writes N bits with value B to the bitstream and advances the bitstream pointer by N bit positions. This function assumes the existence of a bitstream pointer with an indication of the position of the next bit to be written to the bitstream by the encoding process.

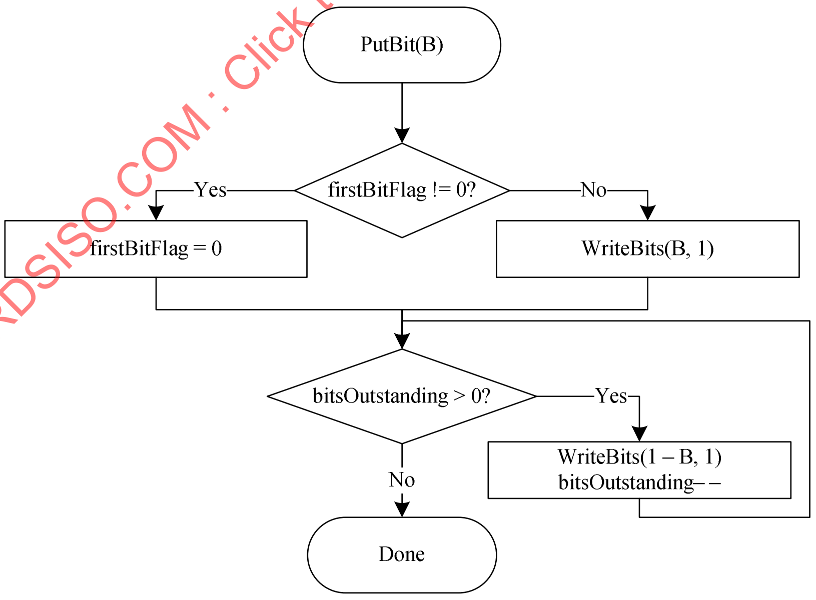


**Figure 9-12 – Flowchart of PutBit(B)**

### 9.3.5.5 Bypass encoding process for binary decisions (informative)

This subclause does not form an integral part of this Specification.

Inputs to this process are the variables binVal, ivlLow, ivlCurrRange, bitsOutstanding, and BinCountsInNalUnits.

Output of this process is a bit written to the RBSP and the updated variables ivlLow, bitsOutstanding, and BinCountsInNalUnits.

This encoding process applies to all binary decisions with bypassFlag equal to 1. Renormalization is included in the specification of this process as given in Figure 9-13.

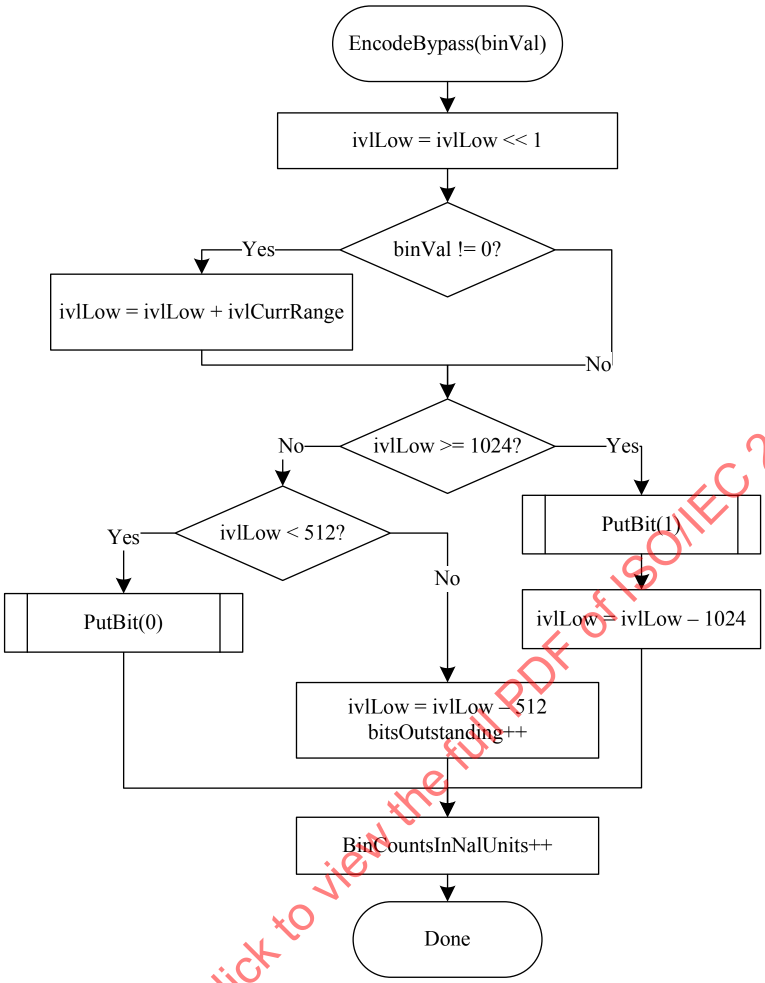


**Figure 9-13 – Flowchart of encoding bypass**

### 9.3.5.6 Encoding process for a binary decision before termination (informative)

This subclause does not form an integral part of this Specification.

Inputs to this process are the variables binVal, ivlCurrRange, ivlLow, bitsOutstanding, and BinCountsInNalUnits.

Outputs of this process are zero or more bits written to the RBSP and the updated variables ivlLow, ivlCurrRange, bitsOutstanding, and BinCountsInNalUnits.

This encoding routine shown in Figure 9-14 applies to encoding of end_of_slice_segment_flag, end_of_sub_stream_one_bit, and pcm_flag, all associated with ctxIdx equal to 0.

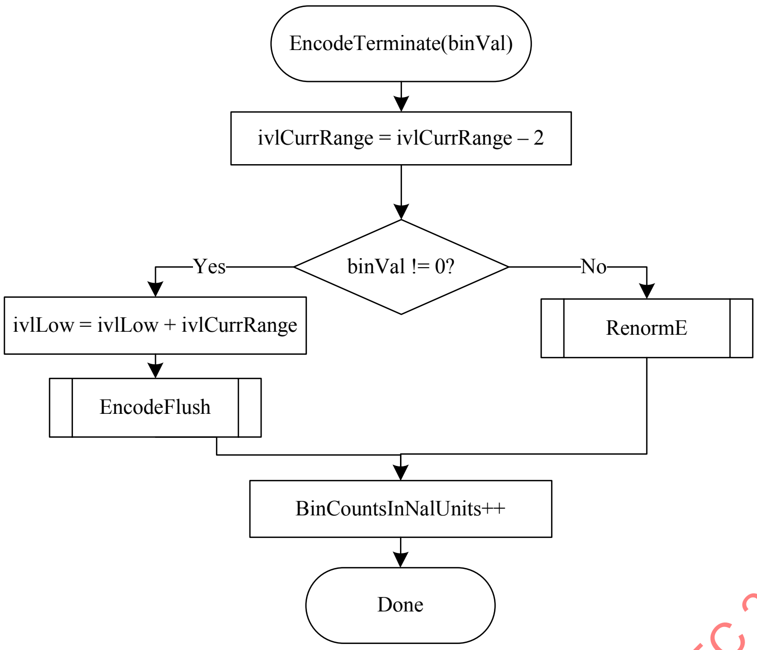


**Figure 9-14 – Flowchart of encoding a decision before termination**

When the value of binVal to encode is equal to 1, CABAC encoding is terminated and the flushing procedure shown in Figure 9-15 is applied. In this flushing procedure, the last bit written by WriteBits( B, N ) is equal to 1. When encoding end_of_slice_segment_flag, this last bit is interpreted as rbsp_stop_one_bit. When encoding end_of_sub_stream_one_bit, this last bit is interpreted as alignment_bit_equal_to_one.

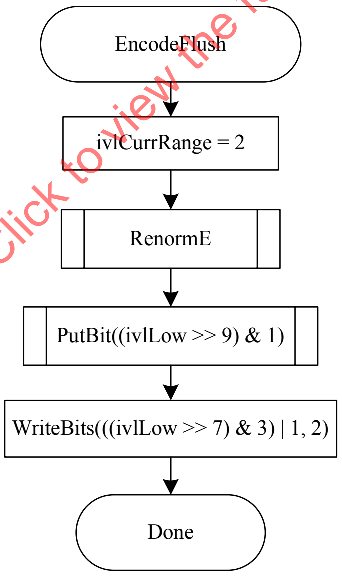

EncodeFlush
ivlCurrRange = 2
RenormE
PutBit((ivlLow >> 9) & 1)
WriteBits(((ivlLow >> 7) & 3) | 1, 2)
Done

**Figure 9-15 – Flowchart of flushing at termination**

### 9.3.5.7 Byte stuffing process (informative)

This subclause does not form an integral part of this Specification.

This process is invoked after encoding the last coding block of the last slice segment of a picture and after encapsulation.

Inputs to this process are the number of bytes NumBytesInVclNalUnits of all VCL NAL units of a picture, the number of minimum CUs PicSizeInMinCbsY in the picture, and the number of binary symbols BinCountsInNalUnits resulting from encoding the contents of all VCL NAL units of the picture.

NOTE – The value of BinCountsInNalUnits is the result of encoding all slice segments of a coded picture. After initializing for the first slice segment of a coded picture as specified in subclause 9.3.5.2, BinCountsInNalUnits is incremented as specified in subclauses 9.3.5.3, 9.3.5.5, and 9.3.5.6.

Outputs of this process are zero or more bytes appended to the NAL unit.

Let the variable k be set equal to Ceil( ( Ceil( 3 * ( 32 * BinCountsInNalUnits − RawMinCuBits * PicSizeInMinCbsY ) ÷ 1024 ) − NumBytesInVclNalUnits ) ÷ 3 ). Depending on the value of k the following applies:

– If k is less than or equal to 0, no cabac_zero_word is appended to the NAL unit.

– Otherwise (k is greater than 0), the 3-byte sequence 0x000003 is appended k times to the NAL unit after encapsulation, where the first two bytes 0x0000 represent a cabac_zero_word and the third byte 0x03 represents an emulation_prevention_three_byte.

## 10 Sub-bitstream extraction process

Inputs to this process are a bitstream, a target highest TemporalId value tIdTarget, and a target layer identifier list layerIdListTarget.

Output of this process is a sub-bitstream.

It is a requirement of bitstream conformance for the input bitstream that any output sub-bitstream of the process specified in this subclause with tIdTarget equal to any value in the range of 0 to 6, inclusive, and layerIdListTarget equal to the layer identifier list associated with a layer set specified in the active video parameter set shall be a conforming bitstream.

NOTE 1 – A conforming bitstream contains one or more coded slice segment NAL units with nuh_layer_id equal to 0 and TemporalId equal to 0.

The output sub-bitstream is derived as follows:

– When one or more of the following two conditions are true, remove all SEI NAL units that have nuh_layer_id equal to 0 and that contain a non-nested buffering period SEI message, a non-nested picture timing SEI message, or a non-nested decoding unit information SEI message:

  – layerIdListTarget does not include all the values of nuh_layer_id in all NAL units in the bitstream.

  – tIdTarget is less than the greatest TemporalId in all NAL units in the bitstream.

  NOTE 2 – A "smart" bitstream extractor may include appropriate non-nested buffering picture SEI messages, non-nested picture timing SEI messages, and non-nested decoding unit information SEI messages in the extracted sub-bitstream, provided that the SEI messages applicable to the sub-bitstream were present as nested SEI messages in the original bitstream.

– Remove all NAL units with TemporalId greater than tIdTarget or nuh_layer_id not among the values included in layerIdListTarget.

# Annex A

# Profiles, tiers and levels

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

## A.1 Overview of profiles, tiers and levels

Profiles, tiers and levels specify restrictions on bitstreams and hence limits on the capabilities needed to decode the bitstreams. Profiles, tiers and levels may also be used to indicate interoperability points between individual decoder implementations.

NOTE 1 – This Specification does not include individually selectable "options" at the decoder, as this would increase interoperability difficulties.

Each profile specifies a subset of algorithmic features and limits that shall be supported by all decoders conforming to that profile.

NOTE 2 – Encoders are not required to make use of any particular subset of features supported in a profile.

Each level of a tier specifies a set of limits on the values that may be taken by the syntax elements of this Specification. The same set of tier and level definitions is used with all profiles, but individual implementations may support a different tier and within a tier a different level for each supported profile. For any given profile, a level of a tier generally corresponds to a particular decoder processing load and memory capability.

The profiles that are specified in subclause A.3 are also referred to as the profiles specified in Annex A.

## A.2 Requirements on video decoder capability

Capabilities of video decoders conforming to this Specification are specified in terms of the ability to decode video streams conforming to the constraints of profiles, tiers and levels specified in this annex. When expressing the capabilities of a decoder for a specified profile, the tier and level supported for that profile should also be expressed.

Specific values are specified in this annex for the syntax elements general_profile_idc, general_tier_flag, and general_level_idc. All other values of general_profile_idc, general_tier_flag, and general_level_idc are reserved for future use by ITU-T | ISO/IEC.

NOTE – Decoders should not infer that a reserved value of general_profile_idc between the values specified in this Specification that this indicates intermediate capabilities between the specified profiles, as there are no restrictions on the method to be chosen by ITU-T | ISO/IEC for the use of such future reserved values. However, decoders should infer that a reserved value of general_level_idc associated with a particular value of general_tier_flag between the values specified in this Specification indicates intermediate capabilities between the specified levels of the tier.

## A.3 Profiles

### A.3.1 General

All constraints for PPSs that are specified are constraints for PPSs that are activated when the bitstream is decoded. All constraints for SPSs that are specified are constraints for SPSs that are activated when the bitstream is decoded.

The variable RawCtuBits is derived as follows:

$$\text{RawCtuBits} = \text{CtbSizeY} * \text{CtbSizeY} * \text{BitDepth}_Y + 2 * ( \text{CtbWidthC} * \text{CtbHeightC} ) * \text{BitDepth}_C \qquad \text{(A-1)}$$

### A.3.2 Main profile

Bitstreams conforming to the Main profile shall obey the following constraints:

– SPSs shall have chroma_format_idc equal to 1 only.

– SPSs shall have bit_depth_luma_minus8 equal to 0 only.

– SPSs shall have bit_depth_chroma_minus8 equal to 0 only.

– CtbLog2SizeY shall be in the range of 4 to 6, inclusive.

– When a PPS has tiles_enabled_flag is equal to 1, it shall have entropy_coding_sync_enabled_flag equal to 0.

– When a PPS has tiles_enabled_flag is equal to 1, ColumnWidthInLumaSamples[ i ] shall be greater than or equal to 256 for all values of i in the range of 0 to num_tile_columns_minus1, inclusive, and RowHeightInLumaSamples[ j ] shall be greater than or equal to 64 for all values of j in the range of 0 to num_tile_rows_minus1, inclusive.

– The number of times read_bits( 1 ) is called in subclauses 9.3.4.3.3 and 9.3.4.3.4 when parsing coding_tree_unit( ) data for any coding tree unit shall be less than or equal to 5 * RawCtuBits / 3.

– The level constraints specified for the Main profile in subclause A.4 shall be fulfilled.

Conformance of a bitstream to the Main profile is indicated by general_profile_idc being equal to 1 or general_profile_compatibility_flag[ 1 ] being equal to 1.

NOTE – When general_profile_compatibility_flag[ 1 ] is equal to 1, general_profile_compatibility_flag[ 2 ] should also be equal to 1.

Decoders conforming to the Main profile at a specific level (identified by a specific value of general_level_idc) of a specific tier (identified by a specific value of general_tier_flag) shall be capable of decoding all bitstreams for which all of the following conditions apply:

– general_profile_compatibility_flag[ 1 ] is equal to 1.

– general_level_idc represents a level lower than or equal to the specified level.

– general_tier_flag represents a tier lower than or equal to the specified tier.

### A.3.3 Main 10 profile

Bitstreams conforming to the Main 10 profile shall obey the following constraints:

– SPSs shall have chroma_format_idc equal to 1 only.

– SPSs shall have bit_depth_luma_minus8 in the range of 0 to 2, inclusive.

– SPSs shall have bit_depth_chroma_minus8 in the range of 0 to 2, inclusive.

– CtbLog2SizeY shall be in the range of 4 to 6, inclusive.

– When a PPS has tiles_enabled_flag is equal to 1, it shall have entropy_coding_sync_enabled_flag equal to 0.

– When a PPS has tiles_enabled_flag is equal to 1, ColumnWidthInLumaSamples[ i ] shall be greater than or equal to 256 for all values of i in the range of 0 to num_tile_columns_minus1, inclusive, and RowHeightInLumaSamples[ j ] shall be greater than or equal to 64 for all values of j in the range of 0 to num_tile_rows_minus1, inclusive.

– The number of times read_bits( 1 ) is called in subclauses 9.3.4.3.3 and 9.3.4.3.4 when parsing coding_tree_unit( ) data for any coding tree unit shall be less than or equal to 5 * RawCtuBits / 3.

– The level constraints specified for the Main 10 profile in subclause A.4 shall be fulfilled.

Conformance of a bitstream to the Main 10 profile is indicated by general_profile_idc being equal to 2 or general_profile_compatibility_flag[ 2 ] being equal to 1.

Decoders conforming to the Main 10 profile at a specific level (identified by a specific value of general_level_idc) shall be capable of decoding all bitstreams for which all of the following conditions apply:

– general_profile_compatibility_flag[ 1 ] is equal to 1 or general_profile_compatibility_flag[ 2 ] is equal to 1.

– general_level_idc represents a level lower than or equal to the specified level.

– general_tier_flag represents a tier lower than or equal to the specified tier.

### A.3.4 Main Still Picture profile

Bitstreams conforming to the Main Still Picture profile shall obey the following constraints:

– The bitstream shall contain only one picture.

– SPSs shall have chroma_format_idc equal to 1 only.

– SPSs shall have bit_depth_luma_minus8 equal to 0 only.

– SPSs shall have bit_depth_chroma_minus8 equal to 0 only.

– SPSs shall have sps_max_dec_pic_buffering_minus1[ sps_max_sub_layers_minus1 ] equal to 0 only.

– CtbLog2SizeY shall be in the range of 4 to 6, inclusive.

– When a PPS has tiles_enabled_flag is equal to 1, it shall have entropy_coding_sync_enabled_flag equal to 0.

– When a PPS has tiles_enabled_flag is equal to 1, ColumnWidthInLumaSamples[ i ] shall be greater than or equal to 256 for all values of i in the range of 0 to num_tile_columns_minus1, inclusive, and RowHeightInLumaSamples[ j ] shall be greater than or equal to 64 for all values of j in the range of 0 to num_tile_rows_minus1, inclusive.

– The number of times read_bits( 1 ) is called in subclauses 9.3.4.3.3 and 9.3.4.3.4 when parsing coding_tree_unit( ) data for any coding tree unit shall be less than or equal to 5 * RawCtuBits / 3.

– The level constraints specified for the Main Still Picture profile in subclause A.4 shall be fulfilled.

Conformance of a bitstream to the Main Still Picture profile is indicated by general_profile_idc being equal to 3 or general_profile_compatibility_flag[ 3 ] being equal to 1.

Decoders conforming to the Main Still Picture profile at a specific level (identified by a specific value of general_level_idc) shall be capable of decoding all bitstreams for which all of the following conditions apply:

– general_profile_compatibility_flag[ 3 ] is equal to 1.

– general_level_idc represents a level lower than or equal to the specified level.

– general_tier_flag represents a tier lower than or equal to the specified tier.

## A.4 Tiers and levels

### A.4.1 General tier and level limits

For purposes of comparison of tier capabilities, the tier with general_tier_flag equal to 0 is considered to be a lower tier than the tier with general_tier_flag equal to 1.

For purposes of comparison of level capabilities, a particular level of a specific tier is considered to be a lower level than some other level of the same tier when the value of the general_level_idc of the particular level is less than that of the other level.

The following is specified for expressing the constraints in this annex:

– Let access unit n be the n-th access unit in decoding order, with the first access unit being access unit 0 (i.e. the 0-th access unit).

– Let picture n be the coded picture or the corresponding decoded picture of access unit n.

– Let the variable CpbBrVclFactor be equal to 1000.

– Let the variable CpbBrNalFactor be equal to 1100.

Bitstreams conforming to a profile at a specified tier and level shall obey the following constraints for each bitstream conformance test as specified in Annex C:

a) PicSizeInSamplesY shall be less than or equal to MaxLumaPs, where MaxLumaPs is specified in Table A-1.

b) The value of pic_width_in_luma_samples shall be less than or equal to Sqrt( MaxLumaPs * 8 ).

c) The value of pic_height_in_luma_samples shall be less than or equal to Sqrt( MaxLumaPs * 8 ).

d) The value of sps_max_dec_pic_buffering_minus1[ HighestTid ] + 1 shall be less than or equal to MaxDpbSize, which is derived as follows:

```
if( PicSizeInSamplesY <= ( MaxLumaPs >> 2 ) )
    MaxDpbSize = Min( 4 * maxDpbPicBuf, 16 )
else if( PicSizeInSamplesY <= ( MaxLumaPs >> 1 ) )
    MaxDpbSize = Min( 2 * maxDpbPicBuf, 16 )                    (A-2)
else if( PicSizeInSamplesY <= ( ( 3 * MaxLumaPs ) >> 2 ) )
    MaxDpbSize = Min( ( 4 * maxDpbPicBuf ) / 3, 16 )
else
    MaxDpbSize = maxDpbPicBuf
```

where MaxLumaPs is specified in Table A-1 and maxDpbPicBuf is equal to 6.

e) For level 5 and higher levels, the value of CtbSizeY shall be equal to 32 or 64.

f) The value of NumPocTotalCurr shall be less than or equal to 8.

g) The value of num_tile_columns_minus1 shall be less than MaxTileCols and num_tile_rows_minus1 shall be less than MaxTileRows, where MaxTileCols and MaxTileRows are specified in Table A-1.

h) For the VCL HRD parameters, CpbSize[ i ] shall be less than or equal to CpbBrVclFactor * MaxCPB for at least one value of i in the range of 0 to cpb_cnt_minus1[ HighestTid ], inclusive, where CpbSize[ i ] is specified in subclause E.2.3 based on parameters selected as specified in subclause C.1 and MaxCPB is specified in Table A-1 in units of CpbBrVclFactor bits.

i) For the NAL HRD parameters, CpbSize[ i ] shall be less than or equal to CpbBrNalFactor * MaxCPB for at least one value of i in the range of 0 to cpb_cnt_minus1[ HighestTid ], inclusive, where CpbSize[ i ] is specified in subclause E.2.3 based on parameters selected as specified in subclause C.1 and MaxCPB is specified in Table A-1 in units of CpbBrNalFactor bits.

Table A-1 specifies the limits for each level of each tier.

A tier and level to which the bitstream conforms are indicated by the syntax elements general_tier_flag and general_level_idc as follows:

– general_tier_flag equal to 0 indicates conformance to the Main tier, and general_tier_flag equal to 1 indicates conformance to the High tier, according to the tier constraints specified in Table A-1. general_tier_flag shall be equal to 0 for levels below level 4 (corresponding to the entries in Table A-1 marked with "-").
– general_level_idc shall be set equal to a value of 30 times the level number specified in Table A-1.

**Table A-1 – General tier and level limits**

| **Level** | **Max luma picture size MaxLumaPs (samples)** | **Max CPB size MaxCPB (1000 bits)** | | **Max slice segments per picture MaxSliceSegmentsPerPicture** | **Max # of tile rows MaxTileRows** | **Max # of tile columns MaxTileCols** |
|---|---|---|---|---|---|---|
| | | **Main tier** | **High tier** | | | |
| **1** | 36 864 | 350 | - | 16 | 1 | 1 |
| **2** | 122 880 | 1 500 | - | 16 | 1 | 1 |
| **2.1** | 245 760 | 3 000 | - | 20 | 1 | 1 |
| **3** | 552 960 | 6 000 | - | 30 | 2 | 2 |
| **3.1** | 983 040 | 10 000 | - | 40 | 3 | 3 |
| **4** | 2 228 224 | 12 000 | 30 000 | 75 | 5 | 5 |
| **4.1** | 2 228 224 | 20 000 | 50 000 | 75 | 5 | 5 |
| **5** | 8 912 896 | 25 000 | 100 000 | 200 | 11 | 10 |
| **5.1** | 8 912 896 | 40 000 | 160 000 | 200 | 11 | 10 |
| **5.2** | 8 912 896 | 60 000 | 240 000 | 200 | 11 | 10 |
| **6** | 35 651 584 | 60 000 | 240 000 | 600 | 22 | 20 |
| **6.1** | 35 651 584 | 120 000 | 480 000 | 600 | 22 | 20 |
| **6.2** | 35 651 584 | 240 000 | 800 000 | 600 | 22 | 20 |

Informative subclause A.4.3 shows the effect of these limits on picture rates for several example picture formats.

### A.4.2 Profile-specific level limits for the Main and Main 10 profiles

The following is specified for expressing the constraints in this annex:

– Let the variable fR be set equal to 1 ÷ 300.

Bitstreams conforming to the Main or Main 10 profile at a specified tier and level shall obey the following constraints for each bitstream conformance test as specified in Annex C:

a) The nominal removal time of access unit n (with n greater than 0) from the CPB, as specified in subclause C.2.3, shall satisfy the constraint that AuNominalRemovalTime[ n ] − AuCpbRemovalTime[ n − 1 ] is greater than or equal to Max( PicSizeInSamplesY ÷ MaxLumaSr, fR ) for the value of PicSizeInSamplesY of picture n − 1, where MaxLumaSr is the value specified in Table A-2 that applies to picture n − 1.

b) The difference between consecutive output times of pictures from the DPB, as specified in subclause C.3.3, shall satisfy the constraint that DpbOutputInterval[ n ] is greater than or equal to Max( PicSizeInSamplesY ÷ MaxLumaSr, fR ) for the value of PicSizeInSamplesY of picture n, where MaxLumaSr is the value specified in Table A-2 for picture n, provided that picture n is a picture that is output and is not the last picture of the bitstream that is output.

c) The removal time of access unit 0 shall satisfy the constraint that the number of slice segments in picture 0 is less than or equal to Min( MaxSliceSegmentsPerPicture * MaxLumaSr / MaxLumaPs * ( AuCpbRemovalTime[ 0 ] − AuNominalRemovalTime[ 0 ] ) + MaxSliceSegmentsPerPicture * PicSizeInSamplesY / MaxLumaPs, MaxSliceSegmentsPerPicture ), for the value of PicSizeInSamplesY of picture 0, where MaxSliceSegmentsPerPicture, MaxLumaPs and MaxLumaSr are the values specified in Table A-1 and Table A-2, respectively, that apply to picture 0.

d) The difference between consecutive CPB removal times of access units n and n − 1 (with n greater than 0) shall satisfy the constraint that the number of slice segments in picture n is less than or equal to Min( MaxSliceSegmentsPerPicture * MaxLumaSr / MaxLumaPs * ( AuCpbRemovalTime[ n ] − AuCpbRemovalTime[ n − 1 ] ), MaxSliceSegmentsPerPicture ), where MaxSliceSegmentsPerPicture, MaxLumaPs and MaxLumaSr are the values specified in Table A-1 and Table A-2, respectively, that apply to picture n.

e) For the VCL HRD parameters, BitRate[ i ] shall be less than or equal to CpbBrVclFactor * MaxBR for at least one value of i in the range of 0 to cpb_cnt_minus1[ HighestTid ], inclusive, where BitRate[ i ] is specified in subclause E.2.3 based on parameters selected as specified in subclause C.1 and MaxBR is specified in Table A-2 in units of CpbBrVclFactor bits/s.

f) For the NAL HRD parameters, BitRate[ i ] shall be less than or equal to CpbBrNalFactor * MaxBR for at least one value of i in the range of 0 to cpb_cnt_minus1[ HighestTid ], inclusive, where BitRate[ i ] is specified in subclause E.2.3 based on parameters selected as specified in subclause C.1 and MaxBR is specified in Table A-2 in units of CpbBrNalFactor bits/s.

g) The sum of the NumBytesInNalUnit variables for access unit 0 shall be less than or equal to 1.5 * ( Max( PicSizeInSamplesY, fR * MaxLumaSr ) + MaxLumaSr * ( AuCpbRemovalTime[ 0 ] − AuNominalRemovalTime[ 0 ] ) ) ÷ MinCr for the value of PicSizeInSamplesY of picture 0, where MaxLumaSr and MinCr are the values specified in Table A-2 that apply to picture 0.

h) The sum of the NumBytesInNalUnit variables for access unit n (with n greater than 0) shall be less than or equal to 1.5 * MaxLumaSr * ( AuCpbRemovalTime[ n ] − AyCpbRemovalTime[ n − 1 ] ) ÷ MinCr, where MaxLumaSr and MinCr are the values specified in Table A-2 that apply to picture n.

i) The removal time of access unit 0 shall satisfy the constraint that the number of tiles in picture 0 is less than or equal to Min( MaxTileCols * MaxTileRows * 120 * ( AuCpbRemovalTime[ 0 ] − AuNominalRemovalTime[ 0 ] ) + MaxTileCols * MaxTileRows * PicSizeInSamplesY / MaxLumaPs, MaxTileCols * MaxTileRows ), for the value of PicSizeInSamplesY of picture 0, where MaxTileCols and MaxTileRows are the values specified in Table A-1 that apply to picture 0.

j) The difference between consecutive CPB removal times of access units n and n − 1 (with n greater than 0) shall satisfy the constraint that the number of tiles in picture n is less than or equal to Min( MaxTileCols * MaxTileRows * 120 * ( AuCpbRemovalTime[ n ] − AuCpbRemovalTime[ n − 1 ] ), MaxTileCols * MaxTileRows ), where MaxTileCols and MaxTileRows are the values specified in Table A-1 that apply to picture n.

k)

**Table A-2 – Tier and level limits for the Main and Main 10 profiles**

| **Level** | **Max luma sample rate MaxLumaSr (samples/sec)** | **Max bit rate MaxBR (1000 bits/s)** | | **Min Compression Ratio MinCr** |
|---|---|---|---|---|
| | | **Main tier** | **High tier** | |
| **1** | 552 960 | 128 | - | 2 |
| **2** | 3 686 400 | 1 500 | - | 2 |
| **2.1** | 7 372 800 | 3 000 | - | 2 |
| **3** | 16 588 800 | 6 000 | - | 2 |
| **3.1** | 33 177 600 | 10 000 | - | 2 |
| **4** | 66 846 720 | 12 000 | 30 000 | 4 |
| **4.1** | 133 693 440 | 20 000 | 50 000 | 4 |
| **5** | 267 386 880 | 25 000 | 100 000 | 6 |
| **5.1** | 534 773 760 | 40 000 | 160 000 | 8 |
| **5.2** | 1 069 547 520 | 60 000 | 240 000 | 8 |
| **6** | 1 069 547 520 | 60 000 | 240 000 | 8 |
| **6.1** | 2 139 095 040 | 120 000 | 480 000 | 8 |
| **6.2** | 4 278 190 080 | 240 000 | 800 000 | 6 |

### A.4.3 Effect of level limits on picture rate for the Main and Main 10 profiles (informative)

This subclause does not form an integral part of this Specification.

Informative Tables A-3 and A-4 provide examples of maximum picture rates for the Main and Main 10 profiles for various picture formats when MinCbSizeY is equal to 64.

**Table A-3 – Maximum picture rates (pictures per second) at level 1 to 4.3 for some example picture sizes when MinCbSizeY is equal to 64**

| **Level:** | | | | **1** | **2** | **2.1** | **3** | **3.1** | **4** | **4.1** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Max luma picture size (samples):** | | | | 36 864 | 122 880 | 245 760 | 552 960 | 983 040 | 2 228 224 | 2 228 224 |
| **Max luma sample rate (samples/sec)** | | | | 552 960 | 3 686 400 | 7 372 800 | 16 588 800 | 33 177 600 | 66 846 720 | 133 693 440 |
| **Format nickname** | **Luma width** | **Luma height** | **Luma picture size** | | | | | | | |
| **SQCIF** | **128** | **96** | 16 384 | 33.7 | 225.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **QCIF** | **176** | **144** | 36 864 | 15.0 | 100.0 | 200.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **QVGA** | **320** | **240** | 81 920 | - | 45.0 | 90.0 | 202.5 | 300.0 | 300.0 | 300.0 |
| **525 SIF** | **352** | **240** | 98 304 | - | 37.5 | 75.0 | 168.7 | 300.0 | 300.0 | 300.0 |
| **CIF** | **352** | **288** | 122 880 | - | 30.0 | 60.0 | 135.0 | 270.0 | 300.0 | 300.0 |
| **525 HHR** | **352** | **480** | 196 608 | - | - | 37.5 | 84.3 | 168.7 | 300.0 | 300.0 |
| **625 HHR** | **352** | **576** | 221 184 | - | - | 33.3 | 75.0 | 150.0 | 300.0 | 300.0 |
| **Q720p** | **640** | **360** | 245 760 | - | - | 30.0 | 67.5 | 135.0 | 272.0 | 300.0 |
| **VGA** | **640** | **480** | 327 680 | - | - | - | 50.6 | 101.2 | 204.0 | 300.0 |
| **525 4SIF** | **704** | **480** | 360 448 | - | - | - | 46.0 | 92.0 | 185.4 | 300.0 |
| **525 SD** | **720** | **480** | 393 216 | - | - | - | 42.1 | 84.3 | 170.0 | 300.0 |
| **4CIF** | **704** | **576** | 405 504 | - | - | - | 40.9 | 81.8 | 164.8 | 300.0 |
| **625 SD** | **720** | **576** | 442 368 | - | - | - | 37.5 | 75.0 | 151.1 | 300.0 |
| **480p (16:9)** | **864** | **480** | 458 752 | - | - | - | 36.1 | 72.3 | 145.7 | 291.4 |
| **SVGA** | **800** | **600** | 532 480 | - | - | - | 31.1 | 62.3 | 125.5 | 251.0 |
| **QHD** | **960** | **540** | 552 960 | - | - | - | 30.0 | 60.0 | 120.8 | 241.7 |
| **XGA** | **1024** | **768** | 786 432 | - | - | - | - | 42.1 | 85.0 | 170.0 |
| **720p HD** | **1280** | **720** | 983 040 | - | - | - | - | 33.7 | 68.0 | 136.0 |
| **4VGA** | **1280** | **960** | 1 228 800 | - | - | - | - | - | 54.4 | 108.8 |
| **SXGA** | **1280** | **1024** | 1 310 720 | - | - | - | - | - | 51.0 | 102.0 |
| **525 16SIF** | **1408** | **960** | 1 351 680 | - | - | - | - | - | 49.4 | 98.9 |
| **16CIF** | **1408** | **1152** | 1 622 016 | - | - | - | - | - | 41.2 | 82.4 |
| **4SVGA** | **1600** | **1200** | 1 945 600 | - | - | - | - | - | 34.3 | 68.7 |
| **1080 HD** | **1920** | **1080** | 2 088 960 | - | - | - | - | - | 32.0 | 64.0 |
| **2Kx1K** | **2048** | **1024** | 2 097 152 | - | - | - | - | - | 31.8 | 63.7 |
| **2Kx1080** | **2048** | **1080** | 2 228 224 | - | - | - | - | - | 30.0 | 60.0 |
| **4XGA** | **2048** | **1536** | 3 145 728 | - | - | - | - | - | - | - |
| **16VGA** | **2560** | **1920** | 4 915 200 | - | - | - | - | - | - | - |
| **3616x1536 (2.35:1)** | **3616** | **1536** | 5 603 328 | - | - | - | - | - | - | - |
| **3672x1536 (2.39:1)** | **3680** | **1536** | 5 701 632 | - | - | - | - | - | - | - |
| **3840x2160 (4*HD)** | **3840** | **2160** | 8 355 840 | - | - | - | - | - | - | - |
| **4Kx2K** | **4096** | **2048** | 8 388 608 | - | - | - | - | - | - | - |
| **4096x2160** | **4096** | **2160** | 8 912 896 | - | - | - | - | - | - | - |
| **4096x2304 (16:9)** | **4096** | **2304** | 9 437 184 | - | - | - | - | - | - | - |
| **7680x4320** | **7680** | **4320** | 33 423 360 | - | - | - | - | - | - | - |
| **8192x4096** | **8192** | **4096** | 33 554 432 | - | - | - | - | - | - | - |
| **8192x4320** | **8192** | **4320** | 35 651 584 | - | - | - | - | - | - | - |

**Table A-4 – Maximum picture rates (pictures per second) at level 5 to 6.2 for some example picture sizes when MinCbSizeY is equal to 64**

| **Level:** | | | | **5** | **5.1** | **5.2** | **6** | **6.1** | **6.2** |
|---|---|---|---|---|---|---|---|---|---|
| **Max luma picture size (samples):** | | | | 8 912 896 | 8 912 896 | 8 912 896 | 35 651 584 | 35 651 584 | 35 651 584 |
| **Max luma sample rate (samples/sec)** | | | | 267 386 880 | 534 773 760 | 1 069 547 520 | 1 069 547 520 | 2 139 095 040 | 4 278 190 080 |
| **Format nickname** | **Luma width** | **Luma height** | **Luma picture size** | | | | | | |
| **SQCIF** | **128** | **96** | 16 384 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **QCIF** | **176** | **144** | 36 864 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **QVGA** | **320** | **240** | 81 920 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **525 SIF** | **352** | **240** | 98 304 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **CIF** | **352** | **288** | 122 880 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **525 HHR** | **352** | **480** | 196 608 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **625 HHR** | **352** | **576** | 221 184 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **Q720p** | **640** | **360** | 245 760 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **VGA** | **640** | **480** | 327 680 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **525 4SIF** | **704** | **480** | 360 448 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **525 SD** | **720** | **480** | 393 216 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **4CIF** | **704** | **576** | 405 504 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **625 SD** | **720** | **576** | 442 368 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **480p (16:9)** | **864** | **480** | 458 752 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **SVGA** | **800** | **600** | 532 480 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **QHD** | **960** | **540** | 552 960 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **XGA** | **1024** | **768** | 786 432 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **720p HD** | **1280** | **720** | 983 040 | 272.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **4VGA** | **1280** | **960** | 1 228 800 | 217.6 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **SXGA** | **1280** | **1024** | 1 310 720 | 204.0 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **525 16SIF** | **1408** | **960** | 1 351 680 | 197.8 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **16CIF** | **1408** | **1152** | 1 622 016 | 164.8 | 300.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **4SVGA** | **1600** | **1200** | 1 945 600 | 137.4 | 274.8 | 300.0 | 300.0 | 300.0 | 300.0 |
| **1080 HD** | **1920** | **1080** | 2 088 960 | 128.0 | 256.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **2Kx1K** | **2048** | **1024** | 2 097 152 | 127.5 | 255.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **2Kx1080** | **2048** | **1080** | 2 228 224 | 120.0 | 240.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **4XGA** | **2048** | **1536** | 3 145 728 | 85.0 | 170.0 | 300.0 | 300.0 | 300.0 | 300.0 |
| **16VGA** | **2560** | **1920** | 4 915 200 | 54.4 | 108.8 | 217.6 | 217.6 | 300.0 | 300.0 |
| **3616x1536 (2.35:1)** | **3616** | **1536** | 5 603 328 | 47.7 | 95.4 | 190.8 | 190.8 | 300.0 | 300.0 |
| **3672x1536 (2.39:1)** | **3680** | **1536** | 5 701 632 | 46.8 | 93.7 | 187.5 | 187.5 | 300.0 | 300.0 |
| **3840x2160 (4*HD)** | **3840** | **2160** | 8 355 840 | 32.0 | 64.0 | 128.0 | 256.0 | 300.0 | 300.0 |
| **4Kx2K** | **4096** | **2048** | 8 388 608 | 31.8 | 63.7 | 127.5 | 127.5 | 255.0 | 300.0 |
| **4096x2160** | **4096** | **2160** | 8 912 896 | 30.0 | 60.0 | 120.0 | 120.0 | 240.0 | 300.0 |
| **4096x2304 (16:9)** | **4096** | **2304** | 9 437 184 | - | - | - | 113.3 | 226.6 | 300.0 |
| **4096x3072** | **4096** | **3072** | 12 582 912 | - | - | - | 85.0 | 170.0 | 300.0 |
| **7680x4320** | **7680** | **4320** | 33 423 360 | - | - | - | 32.0 | 64.0 | 128.0 |
| **8192x4096** | **8192** | **4096** | 33 554 432 | - | - | - | 31.8 | 63.7 | 127.5 |
| **8192x4320** | **8192** | **4320** | 35 651 584 | - | - | - | 30.0 | 60.0 | 120.0 |

The following should be noted in regard to the examples shown in Tables A-3 and A-4:

– This Specification is a variable-picture-size specification. The specific listed picture sizes are illustrative examples only.

– The example luma picture sizes were computed by rounding up the luma width and luma height to multiples of 64 before computing the product of these quantities, to reflect the potential use of MinCbSizeY equal to 64 for these picture sizes, as pic_width_in_luma_samples and pic_height_in_luma_samples are each required to be a multiple of MinCbSizeY. For some illustrated values of luma width and luma height, a somewhat higher number of pictures per second can be supported when MinCbSizeY is less than 64.

– As used in the examples, "525" refers to typical use for environments using 525 analogue scan lines (of which approximately 480 lines contain the visible picture region), and "625" refers to environments using 625 analogue scan lines (of which approximately 576 lines contain the visible picture region).

– XGA is also known as (aka) XVGA, 4SVGA aka UXGA, 16XGA aka 4Kx3K, CIF aka 625 SIF, 625 HHR aka 2CIF aka half 625 D-1, aka half 625 ITU-R BT.601, 525 SD aka 525 D-1 aka 525 ITU-R BT.601, 625 SD aka 625 D-1 aka 625 ITU-R BT.601.

# Annex B

# Byte stream format

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

## B.1 General

This annex specifies syntax and semantics of a byte stream format specified for use by applications that deliver some or all of the NAL unit stream as an ordered stream of bytes or bits within which the locations of NAL unit boundaries need to be identifiable from patterns in the data, such as Rec. ITU-T H.222.0 | ISO/IEC 13818-1 systems or Rec. ITU-T H.320 systems. For bit-oriented delivery, the bit order for the byte stream format is specified to start with the MSB of the first byte, proceed to the LSB of the first byte, followed by the MSB of the second byte, etc.

The byte stream format consists of a sequence of byte stream NAL unit syntax structures. Each byte stream NAL unit syntax structure contains one start code prefix followed by one nal_unit( NumBytesInNalUnit ) syntax structure. It may (and under some circumstances, it shall) also contain an additional zero_byte syntax element. It may also contain one or more additional trailing_zero_8bits syntax elements. When it is the first byte stream NAL unit in the bitstream, it may also contain one or more additional leading_zero_8bits syntax elements.

## B.2 Byte stream NAL unit syntax and semantics

### B.2.1 Byte stream NAL unit syntax

| byte_stream_nal_unit( NumBytesInNalUnit ) { | **Descriptor** |
|---|---|
|   while( next_bits( 24 ) != 0x000001 && next_bits( 32 ) != 0x00000001 ) | |
|     **leading_zero_8bits** /* equal to 0x00 */ | f(8) |
|   if( next_bits( 24 ) != 0x000001 ) | |
|     **zero_byte** /* equal to 0x00 */ | f(8) |
|   **start_code_prefix_one_3bytes** /* equal to 0x000001 */ | f(24) |
|   nal_unit( NumBytesInNalUnit ) | |
|   while( more_data_in_byte_stream( ) && next_bits( 24 ) != 0x000001 && next_bits( 32 ) != 0x00000001 ) | |
|     **trailing_zero_8bits** /* equal to 0x00 */ | f(8) |
| } | |

### B.2.2 Byte stream NAL unit semantics

The order of byte stream NAL units in the byte stream shall follow the decoding order of the NAL units contained in the byte stream NAL units (see subclause 7.4.2.4). The content of each byte stream NAL unit is associated with the same access unit as the NAL unit contained in the byte stream NAL unit (see subclause 7.4.2.4.4).

**leading_zero_8bits** is a byte equal to 0x00.

NOTE – The leading_zero_8bits syntax element can only be present in the first byte stream NAL unit of the bitstream, because (as shown in the syntax diagram of subclause B.2.1) any bytes equal to 0x00 that follow a NAL unit syntax structure and precede the four-byte sequence 0x00000001 (which is to be interpreted as a zero_byte followed by a start_code_prefix_one_3bytes) will be considered to be trailing_zero_8bits syntax elements that are part of the preceding byte stream NAL unit.

**zero_byte** is a single byte equal to 0x00.

When one or more of the following conditions are true, the zero_byte syntax element shall be present:

– The nal_unit_type within the nal_unit( ) syntax structure is equal to VPS_NUT, SPS_NUT or PPS_NUT.

– The byte stream NAL unit syntax structure contains the first NAL unit of an access unit in decoding order, as specified in subclause 7.4.2.4.4.

**start_code_prefix_one_3bytes** is a fixed-value sequence of 3 bytes equal to 0x000001. This syntax element is called a start code prefix.

**trailing_zero_8bits** is a byte equal to 0x00.

## B.3 Byte stream NAL unit decoding process

Input to this process consists of an ordered stream of bytes consisting of a sequence of byte stream NAL unit syntax structures.

Output of this process consists of a sequence of NAL unit syntax structures.

At the beginning of the decoding process, the decoder initializes its current position in the byte stream to the beginning of the byte stream. It then extracts and discards each leading_zero_8bits syntax element (when present), moving the current position in the byte stream forward one byte at a time, until the current position in the byte stream is such that the next four bytes in the bitstream form the four-byte sequence 0x00000001.

The decoder then performs the following step-wise process repeatedly to extract and decode each NAL unit syntax structure in the byte stream until the end of the byte stream has been encountered (as determined by unspecified means) and the last NAL unit in the byte stream has been decoded:

1. When the next four bytes in the bitstream form the four-byte sequence 0x00000001, the next byte in the byte stream (which is a zero_byte syntax element) is extracted and discarded and the current position in the byte stream is set equal to the position of the byte following this discarded byte.
2. The next three-byte sequence in the byte stream (which is a start_code_prefix_one_3bytes) is extracted and discarded and the current position in the byte stream is set equal to the position of the byte following this three-byte sequence.
3. NumBytesInNalUnit is set equal to the number of bytes starting with the byte at the current position in the byte stream up to and including the last byte that precedes the location of one or more of the following conditions:
   – A subsequent byte-aligned three-byte sequence equal to 0x000000,
   – A subsequent byte-aligned three-byte sequence equal to 0x000001,
   – The end of the byte stream, as determined by unspecified means.
4. NumBytesInNalUnit bytes are removed from the bitstream and the current position in the byte stream is advanced by NumBytesInNalUnit bytes. This sequence of bytes is nal_unit( NumBytesInNalUnit ) and is decoded using the NAL unit decoding process.
5. When the current position in the byte stream is not at the end of the byte stream (as determined by unspecified means) and the next bytes in the byte stream do not start with a three-byte sequence equal to 0x000001 and the next bytes in the byte stream do not start with a four byte sequence equal to 0x00000001, the decoder extracts and discards each trailing_zero_8bits syntax element, moving the current position in the byte stream forward one byte at a time, until the current position in the byte stream is such that the next bytes in the byte stream form the four-byte sequence 0x00000001 or the end of the byte stream has been encountered (as determined by unspecified means).

## B.4 Decoder byte-alignment recovery (informative)

This subclause does not form an integral part of this Specification.

Many applications provide data to a decoder in a manner that is inherently byte aligned, and thus have no need for the bit-oriented byte alignment detection procedure described in this subclause.

A decoder is said to have byte alignment with a bitstream when the decoder has determined whether or not the positions of data in the bitstream are byte-aligned. When a decoder does not have byte alignment with the bitstream, the decoder may examine the incoming bitstream for the binary pattern '00000000 00000000 00000000 00000001' (31 consecutive bits equal to 0 followed by a bit equal to 1). The bit immediately following this pattern is the first bit of an aligned byte following a start code prefix. Upon detecting this pattern, the decoder will be byte-aligned with the bitstream and positioned at the start of a NAL unit in the bitstream.

Once byte aligned with the bitstream, the decoder can examine the incoming bitstream data for subsequent three-byte sequences 0x000001 and 0x000003.

When the three-byte sequence 0x000001 is detected, this is a start code prefix.

When the three-byte sequence 0x000003 is detected, the third byte (0x03) is an emulation_prevention_three_byte to be discarded as specified in subclause 7.4.2.

When an error in the bitstream syntax is detected (e.g. a non-zero value of the forbidden_zero_bit or one of the three-byte or four-byte sequences that are prohibited in subclause 7.4.2), the decoder may consider the detected condition as an indication that byte alignment may have been lost and may discard all bitstream data until the detection of byte alignment at a later position in the bitstream as described above in this subclause.

# Annex C

# Hypothetical reference decoder

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

## C.1 General

This annex specifies the hypothetical reference decoder (HRD) and its use to check bitstream and decoder conformance.

Two types of bitstreams or bitstream subsets are subject to HRD conformance checking for this Specification. The first type, called a Type I bitstream, is a NAL unit stream containing only the VCL NAL units and NAL units with nal_unit_type equal to FD_NUT (filler data NAL units) for all access units in the bitstream. The second type, called a Type II bitstream, contains, in addition to the VCL NAL units and filler data NAL units for all access units in the bitstream, at least one of the following:

– additional non-VCL NAL units other than filler data NAL units,

– all leading_zero_8bits, zero_byte, start_code_prefix_one_3bytes, and trailing_zero_8bits syntax elements that form a byte stream from the NAL unit stream (as specified in Annex B).

Figure C-1 shows the types of bitstream conformance points checked by the HRD.

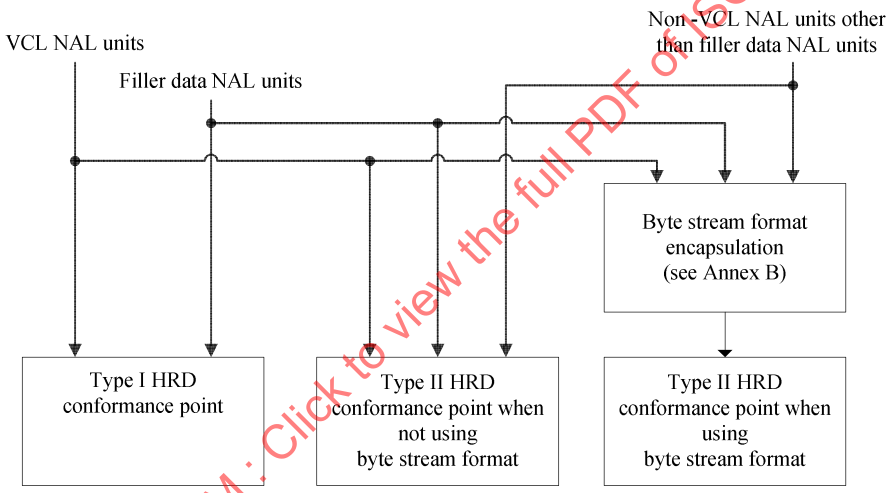

VCL NAL units
Filler data NAL units
Non-VCL NAL units other than filler data NAL units
Byte stream format encapsulation (see Annex B)
Type I HRD conformance point
Type II HRD conformance point when not using byte stream format
Type II HRD conformance point when using byte stream format

**Figure C-1 – Structure of byte streams and NAL unit streams for HRD conformance checks**

The syntax elements of non-VCL NAL units (or their default values for some of the syntax elements), required for the HRD, are specified in the semantic subclauses of clause 7, Annexes D and E.

Two types of HRD parameter sets (NAL HRD parameters and VCL HRD parameters) are used. The HRD parameter sets are signalled through the hrd_parameters( ) syntax structure, which may be part of the SPS syntax structure or the VPS syntax structure.

Multiple tests may be needed for checking the conformance of a bitstream, which is referred to as the bitstream under test. For each test, the following steps apply in the order listed:

1. An operation point under test, denoted as TargetOp, is selected. The layer identifier list OpLayerIdList of TargetOp consists of the list of nuh_layer_id values, in increasing order of nuh_layer_id values, present in the bitstream subset associated with TargetOp, which is a subset of the nuh_layer_id values present in the bitstream under test. The OpTid of TargetOp is equal to the highest TemporalId present in the bitstream subset associated with TargetOp.
2. TargetDecLayerIdList is set equal to OpLayerIdList of TargetOp, HighestTid is set equal to OpTid of TargetOp, and the sub-bitstream extraction process as specified in clause 10 is invoked with the bitstream under test, HighestTid, and TargetDecLayerIdList as inputs, and the output is assigned to BitstreamToDecode.
3. The hrd_parameters( ) syntax structure and the sub_layer_hrd_parameters( ) syntax structure applicable to TargetOp are selected. If TargetDecLayerIdList contains all nuh_layer_id values present in the bitstream under

test, the hrd_parameters( ) syntax structure in the active SPS (or provided through an external means not specified in this Specification) is selected. Otherwise, the hrd_parameters( ) syntax structure in the active VPS (or provided through some external means not specified in this Specification) that applies to TargetOp is selected. Within the selected hrd_parameters( ) syntax structure, if BitstreamToDecode is a Type I bitstream, the sub_layer_hrd_parameters( HighestTid ) syntax structure that immediately follows the condition "if( vcl_hrd_parameters_present_flag )" is selected and the variable NalHrdModeFlag is set equal to 0; otherwise (BitstreamToDecode is a Type II bitstream), the sub_layer_hrd_parameters( HighestTid ) syntax structure that immediately follows either the condition "if( vcl_hrd_parameters_present_flag )" (in this case the variable NalHrdModeFlag is set equal to 0) or the condition "if( nal_hrd_parameters_present_flag )" (in this case the variable NalHrdModeFlag is set equal to 1) is selected. When BitstreamToDecode is a Type II bitstream and NalHrdModeFlag is equal to 0, all non-VCL NAL units except filler data NAL units, and all leading_zero_8bits, zero_byte, start_code_prefix_one_3bytes, and trailing_zero_8bits syntax elements that form a byte stream from the NAL unit stream (as specified in Annex B), when present, are discarded from BitstreamToDecode, and the remaining bitstream is assigned to BitstreamToDecode.

4. An access unit associated with a buffering period SEI message (present in BitstreamToDecode or available through external means not specified in this Specification) applicable to TargetOp is selected as the HRD initialization point and referred to as access unit 0.

5. For each access unit in BitstreamToDecode starting from access unit 0, the buffering period SEI message (present in BitstreamToDecode or available through external means not specified in this Specification) that is associated with the access unit and applies to TargetOp is selected, the picture timing SEI message (present in BitstreamToDecode or available through external means not specified in this Specification) that is associated with the access unit and applies to TargetOp is selected, and when SubPicHrdFlag is equal to 1 and sub_pic_cpb_params_in_pic_timing_sei_flag is equal to 0, the decoding unit information SEI messages (present in BitstreamToDecode or available through external means not specified in this Specification) that are associated with decoding units in the access unit and apply to TargetOp are selected.

6. A value of SchedSelIdx is selected. The selected SchedSelIdx shall be in the range of 0 to cpb_cnt_minus1[ HighestTid ], inclusive, where cpb_cnt_minus1[ HighestTid ] is found in the sub_layer_hrd_parameters( HighestTid ) syntax structure as selected above.

7. When the coded picture in access unit 0 has nal_unit_type equal to CRA_NUT or BLA_W_LP, and irap_cpb_params_present_flag in the selected buffering period SEI message is equal to 1, either of the following applies for selection of the initial CPB removal delay and delay offset:
   - If NalHrdModeFlag is equal to 1, the default initial CPB removal delay and delay offset represented by nal_initial_cpb_removal_delay[ SchedSelIdx ] and nal_initial_cpb_removal_offset[ SchedSelIdx ], respectively, in the selected buffering period SEI message are selected. Otherwise, the default initial CPB removal delay and delay offset represented by vcl_initial_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_cpb_removal_offset[ SchedSelIdx ], respectively, in the selected buffering period SEI message are selected. The variable DefaultInitCpbParamsFlag is set equal to 1.
   - If NalHrdModeFlag is equal to 1, the alternative initial CPB removal delay and delay offset represented by nal_initial_alt_cpb_removal_delay[ SchedSelIdx ] and nal_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, in the selected buffering period SEI message are selected. Otherwise, the alternative initial CPB removal delay and delay offset represented by vcl_initial_alt_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, in the selected buffering period SEI message are selected. The variable DefaultInitCpbParamsFlag is set equal to 0, and the RASL access units associated with access unit 0 are discarded from BitstreamToDecode and the remaining bitstream is assigned to BitstreamToDecode.

8. When sub_pic_hrd_params_present_flag in the selected hrd_parameters( ) syntax structure is equal to 1, the CPB is scheduled to operate either at the access unit level (in which case the variable SubPicHrdFlag is set equal to 0) or at the sub-picture level (in which case the variable SubPicHrdFlag is set equal to 1).

For each operation point under test, the number of bitstream conformance tests to be performed is equal to n0 * n1 * ( n2 * 2 + n3 ) * n4, where the values of n0, n1, n2, n3, and n4 are specified as follows:

- n0 is derived as follows:
  - If BitstreamToDecode is a Type I bitstream, n0 is equal to 1.
  - Otherwise (BitstreamToDecode is a Type II bitstream), n0 is equal to 2.
- n1 is equal to cpb_cnt_minus1[ HighestTid ] + 1.
- n2 is the number of access units in BitstreamToDecode that each is associated with a buffering period SEI message applicable to TargetOp and for each of which both of the following conditions are true:
  - nal_unit_type is equal to CRA_NUT or BLA_W_LP for the VCL NAL units;

    - The associated buffering period SEI message applicable to TargetOp has irap_cpb_params_present_flag equal to 1.
- n3 is the number of access units in BitstreamToDecode BitstreamToDecode that each is associated with a buffering period SEI message applicable to TargetOp and for each of which one or both of the following conditions are true:
    - nal_unit_type is equal to neither CRA_NUT nor BLA_W_LP for the VCL NAL units;
    - The associated buffering period SEI message applicable to TargetOp has irap_cpb_params_present_flag equal to 0.
- n4 is derived as follows:
    - If sub_pic_hrd_params_present_flag in the selected hrd_parameters( ) syntax structure is equal to 0, n4 is equal to 1;
    - Otherwise, n4 is equal to 2.

When BitstreamToDecode is a Type II bitstream, the following applies:

- If the sub_layer_hrd_parameters( HighestTid ) syntax structure that immediately follows the condition "if( vcl_hrd_parameters_present_flag )" is selected, the test is conducted at the Type I conformance point shown in Figure C-1, and only VCL and filler data NAL units are counted for the input bit rate and CPB storage.
- Otherwise (the sub_layer_hrd_parameters( HighestTid ) syntax structure that immediately follows the condition "if( nal_hrd_parameters_present_flag )" is selected), the test is conducted at the Type II conformance point shown in Figure C-1, and all bytes of the Type II bitstream, which may be a NAL unit stream or a byte stream, are counted for the input bit rate and CPB storage.

NOTE 1 – NAL HRD parameters established by a value of SchedSelIdx for the Type II conformance point shown in Figure C-1 are sufficient to also establish VCL HRD conformance for the Type I conformance point shown in Figure C-1 for the same values of InitCpbRemovalDelay[ SchedSelIdx ], BitRate[ SchedSelIdx ], and CpbSize[ SchedSelIdx ] for the VBR case (cbr_flag[ SchedSelIdx ] equal to 0). This is because the data flow into the Type I conformance point is a subset of the data flow into the Type II conformance point and because, for the VBR case, the CPB is allowed to become empty and stay empty until the time a next picture is scheduled to begin to arrive. For example, when decoding a CVS conforming to one or more of the profiles specified in Annex A using the decoding process specified in clauses 2 through 10, when NAL HRD parameters are provided for the Type II conformance point that not only fall within the bounds set for NAL HRD parameters for profile conformance in item f) of subclause A.4.2 but also fall within the bounds set for VCL HRD parameters for profile conformance in item e) of subclause A.4.2, conformance of the VCL HRD for the Type I conformance point is also assured to fall within the bounds of item e) of subclause A.4.2.

All VPSs, SPSs and PPSs referred to in the VCL NAL units, and the corresponding buffering period, picture timing and decoding unit information SEI messages shall be conveyed to the HRD, in a timely manner, either in the bitstream (by non-VCL NAL units), or by other means not specified in this Specification.

In Annexes C, D, and E, the specification for "presence" of non-VCL NAL units that contain VPSs, SPSs, PPSs, buffering period SEI messages, picture timing SEI messages, or decoding unit information SEI messages is also satisfied when those NAL units (or just some of them) are conveyed to decoders (or to the HRD) by other means not specified in this Specification. For the purpose of counting bits, only the appropriate bits that are actually present in the bitstream are counted.

NOTE 2 – As an example, synchronization of such a non-VCL NAL unit, conveyed by means other than presence in the bitstream, with the NAL units that are present in the bitstream, can be achieved by indicating two points in the bitstream, between which the non-VCL NAL unit would have been present in the bitstream, had the encoder decided to convey it in the bitstream.

When the content of such a non-VCL NAL unit is conveyed for the application by some means other than presence within the bitstream, the representation of the content of the non-VCL NAL unit is not required to use the same syntax as specified in this Specification.

NOTE 3 – When HRD information is contained within the bitstream, it is possible to verify the conformance of a bitstream to the requirements of this subclause based solely on information contained in the bitstream. When the HRD information is not present in the bitstream, as is the case for all "stand-alone" Type I bitstreams, conformance can only be verified when the HRD data are supplied by some other means not specified in this Specification.

The HRD contains a coded picture buffer (CPB), an instantaneous decoding process, a decoded picture buffer (DPB), and output cropping as shown in Figure C-2.

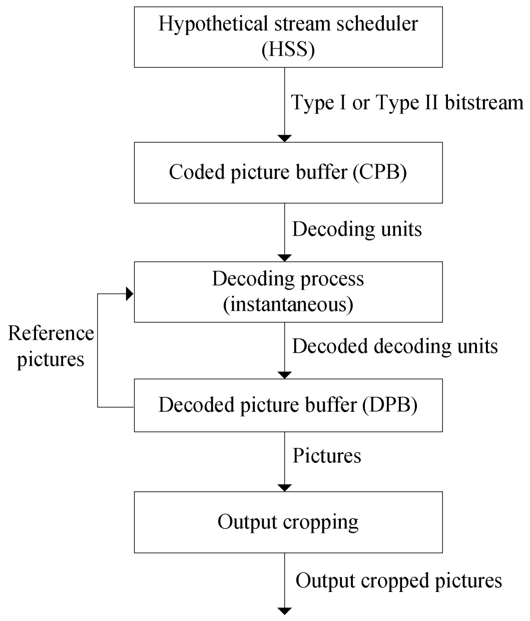

Hypothetical stream scheduler (HSS)
Type I or Type II bitstream
Coded picture buffer (CPB)
Decoding units
Decoding process (instantaneous)
Reference pictures
Decoded decoding units
Decoded picture buffer (DPB)
Pictures
Output cropping
Output cropped pictures

**Figure C-2 – HRD buffer model**

For each bitstream conformance test, the CPB size (number of bits) is CpbSize[ SchedSelIdx ] as specified in subclause E.2.3, where SchedSelIdx and the HRD parameters are specified above in this subclause. The DPB size (number of picture storage buffers) is sps_max_dec_pic_buffering_minus1[ HighestTid ] + 1.

The variable SubPicHrdPreferredFlag is either specified by external means, or when not specified by external means, set equal to 0.

When the value of the variable SubPicHrdFlag has not been set by step 8 above in this subclause, it is derived as follows:

SubPicHrdFlag = SubPicHrdPreferredFlag && sub_pic_hrd_params_present_flag (C-1)

If SubPicHrdFlag is equal to 0, the HRD operates at access unit level and each decoding unit is an access unit. Otherwise the HRD operates at sub-picture level and each decoding unit is a subset of an access unit.

NOTE 4 – If the HRD operates at access unit level, each time a decoding unit that is an entire access unit is removed from the CPB. Otherwise (the HRD operates at sub-picture level), each time a decoding unit that is a subset of an access unit is removed from the CPB. In both cases, each time an entire decoded picture is output from the DPB, though the picture output time is derived based on the differently derived CPB removal times and the differently signalled DPB output delays.

The following is specified for expressing the constraints in this annex:

– Each access unit is referred to as access unit n, where the number n identifies the particular access unit. Access unit 0 is selected per step 4 above. The value of n is incremented by 1 for each subsequent access unit in decoding order.

– Each decoding unit is referred to as decoding unit m, where the number m identifies the particular decoding unit. The first decoding unit in decoding order in access unit 0 is referred to as decoding unit 0. The value of m is incremented by 1 for each subsequent decoding unit in decoding order.

  NOTE 5 – The numbering of decoding units is relative to the first decoding unit in access unit 0.

– Picture n refers to the coded picture or the decoded picture of access unit n.

The HRD operates as follows:

– The HRD is initialized at decoding unit 0, with the both the CPB and the DPB being set to be empty (the DPB fullness is set equal to 0).

  NOTE 6 – After initialization, the HRD is not initialized again by subsequent buffering period SEI messages.

– Data associated with decoding units that flow into the CPB according to a specified arrival schedule are delivered by the HSS.

– The data associated with each decoding unit are removed and decoded instantaneously by the instantaneous decoding process at the CPB removal time of the decoding unit.

– Each decoded picture is placed in the DPB.

– A decoded picture is removed from the DPB when it becomes no longer needed for inter prediction reference and no longer needed for output.

For each bitstream conformance test, the operation of the CPB is specified in subclause C.2, the instantaneous decoder operation is specified in clauses 2 through 10, the operation of the DPB is specified in subclause C.3, and the output cropping is specified in subclause C.3.3 and subclause C.5.2.2.

HSS and HRD information concerning the number of enumerated delivery schedules and their associated bit rates and buffer sizes is specified in subclauses E.1.2 and E.2.2. The HRD is initialized as specified by the buffering period SEI message specified in subclauses D.2.2 and D.3.2. The removal timing of decoding units from the CPB and output timing of decoded pictures from the DPB is specified using information in picture timing SEI messages (specified in subclauses D.2.3 and D.3.3) or in decoding unit information SEI messages (specified in subclauses D.2.21 and D.3.21). All timing information relating to a specific decoding unit shall arrive prior to the CPB removal time of the decoding unit.

The requirements for bitstream conformance are specified in subclause C.4, and the HRD is used to check conformance of bitstreams as specified above in this subclause and to check conformance of decoders as specified in subclause C.5.

NOTE 7 – While conformance is guaranteed under the assumption that all picture-rates and clocks used to generate the bitstream match exactly the values signalled in the bitstream, in a real system each of these may vary from the signalled or specified value.

All the arithmetic in this annex is performed with real values, so that no rounding errors can propagate. For example, the number of bits in a CPB just prior to or after removal of a decoding unit is not necessarily an integer.

The variable ClockTick is derived as follows and is called a clock tick:

$$\text{ClockTick} = \text{vui\_num\_units\_in\_tick} \div \text{vui\_time\_scale} \qquad \text{(C-2)}$$

The variable ClockSubTick is derived as follows and is called a clock sub-tick:

$$\text{ClockSubTick} = \text{ClockTick} \div (\text{tick\_divisor\_minus2} + 2) \qquad \text{(C-3)}$$

## C.2 Operation of coded picture buffer (CPB)

### C.2.1 General

The specifications in this subclause apply independently to each set of CPB parameters that is present and to both the Type I and Type II conformance points shown in Figure C-1, and the set of CPB parameters is selected as specified in subclause C.1.

### C.2.2 Timing of decoding unit arrival

If SubPicHrdFlag is equal to 0, the variable subPicParamsFlag is set equal to 0, and the process in specified in the remainder of this subclause is invoked with a decoding unit being considered as an access unit, for derivation of the initial and final CPB arrival times for access unit n.

Otherwise (SubPicHrdFlag is equal to 1), the process in specified in the remainder of this subclause is first invoked with the variable subPicParamsFlag set equal to 0 and a decoding unit being considered as an access unit, for derivation of the initial and final CPB arrival times for access unit n, and then invoked with subPicParamsFlag set equal to 1 and a decoding unit being considered as a subset of an access unit, for derivation of the initial and final CPB arrival times for the decoding units in access unit n.

The variables InitCpbRemovalDelay[ SchedSelIdx ] and InitCpbRemovalDelayOffset[ SchedSelIdx ] are derived as follows:

– If one or more of the following conditions are true, InitCpbRemovalDelay[ SchedSelIdx ] and InitCpbRemovalDelayOffset[ SchedSelIdx ] are set equal to the values of the buffering period SEI message syntax elements nal_initial_alt_cpb_removal_delay[ SchedSelIdx ] and nal_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 1, or vcl_initial_alt_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 0, where the buffering period SEI message syntax elements are selected as specified in subclause C.1:
  – Access unit 0 is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_RADL or BLA_N_LP, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1.
  – Access unit 0 is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_LP or is a CRA access unit, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1, and one or more of the following conditions are true:
    – UseAltCpbParamsFlag for access unit 0 is equal to 1.

    – DefaultInitCpbParamsFlag is equal to 0.

  – The value of subPicParamsFlag is equal to 1.

– Otherwise, InitCpbRemovalDelay[ SchedSelIdx ] and InitCpbRemovalDelayOffset[ SchedSelIdx ] are set equal to the values of the buffering period SEI message syntax elements nal_initial_cpb_removal_delay[ SchedSelIdx ] and nal_initial_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 1, or vcl_initial_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 0, where the buffering period SEI message syntax elements are selected as specified in subclause C.1.

The time at which the first bit of decoding unit m begins to enter the CPB is referred to as the initial arrival time initArrivalTime[ m ].

The initial arrival time of decoding unit m is derived as follows:

– If the decoding unit is decoding unit 0 (i.e. m = 0), initArrivalTime[ 0 ] = 0,

– Otherwise (the decoding unit is decoding unit m with m > 0), the following applies:

  – If cbr_flag[ SchedSelIdx ] is equal to 1, the initial arrival time for decoding unit m is equal to the final arrival time (which is derived below) of decoding unit m − 1, i.e.

```
if( !subPicParamsFlag )
    initArrivalTime[ m ] = AuFinalArrivalTime[ m − 1 ]                              (C-4)
else
    initArrivalTime[ m ] = DuFinalArrivalTime[ m − 1 ]
```

  – Otherwise (cbr_flag[ SchedSelIdx ] is equal to 0), the initial arrival time for decoding unit m is derived as follows:

```
if( !subPicParamsFlag )
    initArrivalTime[ m ] = Max( AuFinalArrivalTime[ m − 1 ], initArrivalEarliestTime[ m ] )    (C-5)
else
    initArrivalTime[ m ] = Max( DuFinalArrivalTime[ m − 1 ], initArrivalEarliestTime[ m ] )
```

  where initArrivalEarliestTime[ m ] is derived as follows:

    – The variable tmpNominalRemovalTime is derived as follows:

```
if( !subPicParamsFlag )
    tmpNominalRemovalTime = AuNominalRemovalTime[ m ]                               (C-6)
else
    tmpNominalRemovalTime = DuNominalRemovalTime[ m ]
```

    where AuNominalRemovalTime[ m ] and DuNominalRemovalTime[ m ] are the nominal CPB removal time of access unit m and decoding unit m, respectively, as specified in subclause C.2.3.

    – If decoding unit m is not the first decoding unit of a subsequent buffering period, initArrivalEarliestTime[ m ] is derived as follows:

$$\text{initArrivalEarliestTime[ m ]} = \text{tmpNominalRemovalTime} - (\text{ InitCpbRemovalDelay[ SchedSelIdx ]} + \text{InitCpbRemovalDelayOffset[ SchedSelIdx ] }) \div 90000 \quad \text{(C-7)}$$

    – Otherwise (decoding unit m is the first decoding unit of a subsequent buffering period), initArrivalEarliestTime[ m ] is derived as follows:

$$\text{initArrivalEarliestTime[ m ]} = \text{tmpNominalRemovalTime} - (\text{ InitCpbRemovalDelay[ SchedSelIdx ]} \div 90000 \text{ }) \quad \text{(C-8)}$$

The final arrival time for decoding unit m is derived as follows:

```
if( !subPicParamsFlag )
    AuFinalArrivalTime[ m ] = initArrivalTime[ m ] + sizeInbits[ m ] ÷ BitRate[ SchedSelIdx ]     (C-9)
else
    DuFinalArrivalTime[ m ] = initArrivalTime[ m ] + sizeInbits[ m ] ÷ BitRate[ SchedSelIdx ]
```

where sizeInbits[ m ] is the size in bits of decoding unit m, counting the bits of the VCL NAL units and the filler data NAL units for the Type I conformance point or all bits of the Type II bitstream for the Type II conformance point, where the Type I and Type II conformance points are as shown in Figure C-1.

The values of SchedSelIdx, BitRate[ SchedSelIdx ], and CpbSize[ SchedSelIdx ] are constrained as follows:

– If the content of the selected hrd_parameters( ) syntax structures for the access unit containing decoding unit m and the previous access unit differ, the HSS selects a value SchedSelIdx1 of SchedSelIdx from among the values of SchedSelIdx provided in the selected hrd_parameters( ) syntax structures for the access unit containing decoding unit m that results in a BitRate[ SchedSelIdx1 ] or CpbSize[ SchedSelIdx1 ] for the access unit containing decoding unit m. The value of BitRate[ SchedSelIdx1 ] or CpbSize[ SchedSelIdx1 ] may differ from the value of BitRate[ SchedSelIdx0 ] or CpbSize[ SchedSelIdx0 ] for the value SchedSelIdx0 of SchedSelIdx that was in use for the previous access unit.

– Otherwise, the HSS continues to operate with the previous values of SchedSelIdx, BitRate[ SchedSelIdx ] and CpbSize[ SchedSelIdx ].

When the HSS selects values of BitRate[ SchedSelIdx ] or CpbSize[ SchedSelIdx ] that differ from those of the previous access unit, the following applies:

– The variable BitRate[ SchedSelIdx ] comes into effect at the initial CPB arrival time of the current access unit.

– The variable CpbSize[ SchedSelIdx ] comes into effect as follows:

  – If the new value of CpbSize[ SchedSelIdx ] is greater than the old CPB size, it comes into effect at the initial CPB arrival time of the current access unit.

  – Otherwise, the new value of CpbSize[ SchedSelIdx ] comes into effect at the CPB removal time of the current access unit.

## C.2.3 Timing of decoding unit removal and decoding of decoding unit

The variables InitCpbRemovalDelay[ SchedSelIdx ], InitCpbRemovalDelayOffset[ SchedSelIdx ], CpbDelayOffset, and DpbDelayOffset are derived as follows:

– If one or more of the following conditions are true, CpbDelayOffset is set equal to the value of the buffering period SEI message syntax element cpb_delay_offset, DpbDelayOffset is set equal to the value of the buffering period SEI message syntax element dpb_delay_offset, and InitCpbRemovalDelay[ SchedSelIdx ] and InitCpbRemovalDelayOffset[ SchedSelIdx ] are set equal to the values of the buffering period SEI message syntax elements nal_initial_alt_cpb_removal_delay[ SchedSelIdx ] and nal_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 1, or vcl_initial_alt_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_alt_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 0, where the buffering period SEI message containing the syntax elements is selected as specified in subclause C.1:

  – Access unit 0 is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_RADL or BLA_N_LP, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1.

  – Access unit 0 is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_LP or is a CRA access unit, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1, and one or more of the following conditions are true:

    – UseAltCpbParamsFlag for access unit 0 is equal to 1.

    – DefaultInitCpbParamsFlag is equal to 0.

– Otherwise, InitCpbRemovalDelay[ SchedSelIdx ] and InitCpbRemovalDelayOffset[ SchedSelIdx ] are set equal to the values of the buffering period SEI message syntax elements nal_initial_cpb_removal_delay[ SchedSelIdx ] and nal_initial_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 1, or vcl_initial_cpb_removal_delay[ SchedSelIdx ] and vcl_initial_cpb_removal_offset[ SchedSelIdx ], respectively, when NalHrdModeFlag is equal to 0, where the buffering period SEI message containing the syntax elements is selected as specified in subclause C.1, CpbDelayOffset and DpbDelayOffset are both set equal to 0.

The nominal removal time of the access unit n from the CPB is specified as follows:

– If access unit n is the access unit with n equal to 0 (the access unit that initializes the HRD), the nominal removal time of the access unit from the CPB is specified by:

$$\text{AuNominalRemovalTime}[\ 0\ ] = \text{InitCpbRemovalDelay}[\ \text{SchedSelIdx}\ ] \div 90000 \qquad \text{(C-10)}$$

– Otherwise, the following applies:

  – When access unit n is the first access unit of a buffering period that does not initialize the HRD, the following applies:

    The nominal removal time of the access unit n from the CPB is specified by:

```
if( !concatenationFlag ) {
    baseTime = AuNominalRemovalTime[ firstPicInPrevBuffPeriod ]
```

```
        tmpCpbRemovalDelay = AuCpbRemovalDelayVal
    } else {
        baseTime = AuNominalRemovalTime[ prevNonDiscardablePic ]
        tmpCpbRemovalDelay =
            Max( ( auCpbRemovalDelayDeltaMinus1 + 1 ),                                          (C-11)
                Ceil( ( InitCpbRemovalDelay[ SchedSelIdx ] ÷ 90000 +
                    AuFinalArrivalTime[ n − 1 ] − AuNominalRemovalTime[ n − 1 ] ) ÷ ClockTick )
    }
    AuNominalRemovalTime( n ) = baseTime + ClockTick * ( tmpCpbRemovalDelay − CpbDelayOffset )
```

where AuNominalRemovalTime[ firstPicInPrevBuffPeriod ] is the nominal removal time of the first access unit of the previous buffering period, AuNominalRemovalTime[ prevNonDiscardablePic ] is the nominal removal time of the preceding picture in decoding order with TemporalId equal to 0 that is not a RASL, RADL or sub-layer non-reference picture, AuCpbRemovalDelayVal is the value of AuCpbRemovalDelayVal derived according to au_cpb_removal_delay_minus1 in the picture timing SEI message, selected as specified in subclause C.1, associated with access unit n, and concatenationFlag and auCpbRemovalDelayDeltaMinus1 are the values of the syntax elements concatenation_flag and au_cpb_removal_delay_delta_minus1, respectively, in the buffering period SEI message, selected as specified in subclause C.1, associated with access unit n.

After the derivation of the nominal CPB removal time and before the derivation of the DPB output time of access unit n, the values of CpbDelayOffset and DpbDelayOffset are updated as follows:

– If one or more of the following conditions are true, CpbDelayOffset is set equal to the value of the buffering period SEI message syntax element cpb_delay_offset, and DpbDelayOffset is set equal to the value of the buffering period SEI message syntax element dpb_delay_offset, where the buffering period SEI message containing the syntax elements is selected as specified in subclause C.1:

  – Access unit n is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_RADL or BLA_N_LP, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1.

  – Access unit n is a BLA access unit for which the coded picture has nal_unit_type equal to BLA_W_LP or is a CRA access unit, and the value of irap_cpb_params_present_flag of the buffering period SEI message is equal to 1, and UseAltCpbParamsFlag for access unit n is equal to 1.

– Otherwise, CpbDelayOffset and DpbDelayOffset are both set equal to 0.

– When access unit n is not the first access unit of a buffering period, the nominal removal time of the access unit n from the CPB is specified by:

$$\text{AuNominalRemovalTime}[\ n\ ] = \text{AuNominalRemovalTime}[\ \text{firstPicInCurrBuffPeriod}\ ] + \text{ClockTick} * (\ \text{AuCpbRemovalDelayVal} - \text{CpbDelayOffset}\ ) \quad \text{(C-12)}$$

where AuNominalRemovalTime[ firstPicInCurrBuffPeriod ] is the nominal removal time of the first access unit of the current buffering period, and AuCpbRemovalDelayVal is the value of AuCpbRemovalDelayVal derived according to au_cpb_removal_delay_minus1 in the picture timing SEI message, selected as specified in subclause C.1, associated with access unit n.

When SubPicHrdFlag is equal to 1, the following applies:

– The variable duCpbRemovalDelayInc is derived as follows:

  – If sub_pic_cpb_params_in_pic_timing_sei_flag is equal to 0, duCpbRemovalDelayInc is set equal to the value of du_spt_cpb_removal_delay_increment in the decoding unit information SEI message, selected as specified in subclause C.1, associated with decoding unit m.

  – Otherwise, if du_common_cpb_removal_delay_flag is equal to 0, duCpbRemovalDelayInc is set equal to the value of du_cpb_removal_delay_increment_minus1[ i ] + 1 for decoding unit m in the picture timing SEI message, selected as specified in subclause C.1, associated with access unit n, where the value of i is 0 for the first num_nalus_in_du_minus1[ 0 ] + 1 consecutive NAL units in the access unit that contains decoding unit m, 1 for the subsequent num_nalus_in_du_minus1[ 1 ] + 1 NAL units in the same access unit, 2 for the subsequent num_nalus_in_du_minus1[ 2 ] + 1 NAL units in the same access unit, etc.

  – Otherwise, duCpbRemovalDelayInc is set equal to the value of du_common_cpb_removal_delay_increment_minus1 + 1 in the picture timing SEI message, selected as specified in subclause C.1, associated with access unit n.

– The nominal removal time of decoding unit m from the CPB is specified as follows, where AuNominalRemovalTime[ n ] is the nominal removal time of access unit n:

– If decoding unit m is the last decoding unit in access unit n, the nominal removal time of decoding unit m DuNominalRemovalTime[ m ] is set equal to AuNominalRemovalTime[ n ].

– Otherwise (decoding unit m is not the last decoding unit in access unit n), the nominal removal time of decoding unit m DuNominalRemovalTime[ m ] is derived as follows:

```
if( sub_pic_cpb_params_in_pic_timing_sei_flag )
    DuNominalRemovalTime[ m ] = DuNominalRemovalTime[ m + 1 ] −
        ClockSubTick * duCpbRemovalDelayInc                                    (C-13)
else
    DuNominalRemovalTime[ m ] = AuNominalRemovalTime( n ) −
        ClockSubTick * duCpbRemovalDelayInc
```

If SubPicHrdFlag is equal to 0, the removal time of access unit n from the CPB is specified as follows, where AuFinalArrivalTime[ n ] and AuNominalRemovalTime[ n ] are the final CPB arrival time and nominal CPB removal time, respectively, of access unit n:

```
if( !low_delay_hrd_flag[ HighestTid ] | | AuNominalRemovalTime[ n ] >= AuFinalArrivalTime[ n ] )
    AuCpbRemovalTime[ n ] = AuNominalRemovalTime[ n ]
else                                                                            (C-14)
    AuCpbRemovalTime[ n ] = AuNominalRemovalTime[ n ] + ClockTick *
        Ceil( ( AuFinalArrivalTime[ n ] − AuNominalRemovalTime[ n ] ) ÷ ClockTick )
```

NOTE 1 – When low_delay_hrd_flag[ HighestTid ] is equal to 1 and AuNominalRemovalTime[ n ] is less than AuFinalArrivalTime[ n ], the size of access unit n is so large that it prevents removal at the nominal removal time.

Otherwise (SubPicHrdFlag is equal to 1), the removal time of decoding unit m from the CPB is specified as follows:

```
if( !low_delay_hrd_flag[ HighestTid ] | | DuNominalRemovalTime[ m ] >= DuFinalArrivalTime[ m ] )
    DuCpbRemovalTime[ m ] = DuNominalRemovalTime[ m ]
else                                                                            (C-15)
    DuCpbRemovalTime[ m ] = DuFinalArrivalTime[ m ]
```

NOTE 2 – When low_delay_hrd_flag[ HighestTid ] is equal to 1 and DuNominalRemovalTime[ m ] is less than DuFinalArrivalTime[ m ], the size of decoding unit m is so large that it prevents removal at the nominal removal time.

If SubPicHrdFlag is equal to 0, at the CPB removal time of access unit n, the access unit is instantaneously decoded.

Otherwise (SubPicHrdFlag is equal to 1), at the CPB removal time of decoding unit m, the decoding unit is instantaneously decoded, and when decoding unit m is the last decoding unit of access unit n, the following applies:

– Picture n is considered as decoded.

– The final CPB arrival time of access unit n, i.e. AuFinalArrivalTime[ n ], is set equal to the final CPB arrival time of the last decoding unit in access unit n, i.e. DuFinalArrivalTime[ m ].

– The nominal CPB removal time of access unit n, i.e. AuNominalRemovalTime[ n ], is set equal to the nominal CPB removal time of the last decoding unit in access unit n, i.e. DuNominalRemovalTime[ m ].

– The CPB removal time of access unit n, i.e. AuCpbRemovalTime[ m ], is set equal to the CPB removal time of the last decoding unit in access unit n, i.e. DuCpbRemovalTime[ m ].

## C.3 Operation of the decoded picture buffer (DPB)

### C.3.1 General

The specifications in this subclause apply independently to each set of DPB parameters selected as specified in subclause C.1.

The decoded picture buffer contains picture storage buffers. Each of the picture storage buffers may contain a decoded picture that is marked as "used for reference" or is held for future output. The processes specified in subclauses C.3.2, C.3.3 and C.3.4 are sequentially applied as specified below.

### C.3.2 Removal of pictures from the DPB

The removal of pictures from the DPB before decoding of the current picture (but after parsing the slice header of the first slice of the current picture) happens instantaneously at the CPB removal time of the first decoding unit of access unit n (containing the current picture) and proceeds as follows:

– The decoding process for RPS as specified in subclause 8.3.2 is invoked.

– When the current picture is an IRAP picture with NoRaslOutputFlag equal to 1 that is not picture 0, the following ordered steps are applied:

1. The variable NoOutputOfPriorPicsFlag is derived for the decoder under test as follows:

   – If the current picture is a CRA picture, NoOutputOfPriorPicsFlag is set equal to 1 (regardless of the value of no_output_of_prior_pics_flag).

   – Otherwise, if the value of pic_width_in_luma_samples, pic_height_in_luma_samples, or sps_max_dec_pic_buffering_minus1[ HighestTid ] derived from the active SPS is different from the value of pic_width_in_luma_samples, pic_height_in_luma_samples, or sps_max_dec_pic_buffering_minus1[ HighestTid ], respectively, derived from the SPS active for the preceding picture, NoOutputOfPriorPicsFlag may (but should not) be set to 1 by the decoder under test, regardless of the value of no_output_of_prior_pics_flag.

     NOTE – Although setting NoOutputOfPriorPicsFlag equal to no_output_of_prior_pics_flag is preferred under these conditions, the decoder under test is allowed to set NoOutputOfPriorPicsFlag to 1 in this case.

   – Otherwise, NoOutputOfPriorPicsFlag is set equal to no_output_of_prior_pics_flag.

2. The value of NoOutputOfPriorPicsFlag derived for the decoder under test is applied for the HRD, such that when the value of NoOutputOfPriorPicsFlag is equal to 1, all picture storage buffers in the DPB are emptied without output of the pictures they contain, and the DPB fullness is set equal to 0.

– When both of the following conditions are true for any pictures k in the DPB, all such pictures k in the DPB are removed from the DPB:

  – picture k is marked as "unused for reference"

  – picture k has PicOutputFlag equal to 0 or its DPB output time is less than or equal to the CPB removal time of the first decoding unit (denoted as decoding unit m) of the current picture n; i.e. DpbOutputTime[ k ] is less than or equal to CpbRemovalTime( m )

– For each picture that is removed from the DPB, the DPB fullness is decremented by one.

### C.3.3 Picture output

The processes specified in this subclause happen instantaneously at the CPB removal time of access unit n, AuCpbRemovalTime[ n ].

When picture n has PicOutputFlag equal to 1, its DPB output time DpbOutputTime[ n ] is derived as follows, where the variable firstPicInBufferingPeriodFlag is equal to 1 if access unit n is the first access unit of a buffering period and 0 otherwise:

```
if( !SubPicHrdFlag ) {
    DpbOutputTime[ n ] = AuCpbRemovalTime[ n ] + ClockTick * picDpbOutputDelay          (C-16)
    if( firstPicInBufferingPeriodFlag )
        DpbOutputTime[ n ] −= ClockTick * DpbDelayOffset
} else
    DpbOutputTime[ n ] = AuCpbRemovalTime[ n ] + ClockSubTick * picSptDpbOutputDuDelay
```

where picDpbOutputDelay is the value of pic_dpb_output_delay in the picture timing SEI message associated with access unit n, and picSptDpbOutputDuDelay is the value of pic_spt_dpb_output_du_delay, when present, in the decoding unit information SEI messages associated with access unit n, or the value of pic_dpb_output_du_delay in the picture timing SEI message associated with access unit n when there is no decoding unit information SEI message associated with access unit n or no decoding unit information SEI message associated with access unit n has pic_spt_dpb_output_du_delay present.

NOTE – When the syntax element pic_spt_dpb_output_du_delay is not present in any decoding unit information SEI message associated with access unit n, the value is inferred to be equal to pic_dpb_output_du_delay in the picture timing SEI message associated with access unit n.

The output of the current picture is specified as follows:

– If PicOutputFlag is equal to 1 and DpbOutputTime[ n ] is equal to AuCpbRemovalTime[ n ], the current picture is output.

– Otherwise, if PicOutputFlag is equal to 0, the current picture is not output, but will be stored in the DPB as specified in subclause C.3.4.

– Otherwise (PicOutputFlag is equal to 1 and DpbOutputTime[ n ] is greater than AuCpbRemovalTime[ n ] ), the current picture is output later and will be stored in the DPB (as specified in subclause C.3.4) and is output at time

DpbOutputTime[ n ] unless indicated not to be output by the decoding or inference of no_output_of_prior_pics_flag equal to 1 at a time that precedes DpbOutputTime[ n ].

When output, the picture is cropped, using the conformance cropping window specified in the active SPS for the picture.

When picture n is a picture that is output and is not the last picture of the bitstream that is output, the value of the variable DpbOutputInterval[ n ] is derived as follows:

$$\text{DpbOutputInterval[ n ] = DpbOutputTime[ nextPicInOutputOrder ]} - \text{DpbOutputTime[ n ]} \qquad \text{(C-17)}$$

where nextPicInOutputOrder is the picture that follows picture n in output order and has PicOutputFlag equal to 1.

### C.3.4 Current decoded picture marking and storage

The process specified in this subclause happens instantaneously at the CPB removal time of access unit n, CpbRemovalTime[ n ].

The current decoded picture is stored in the DPB in an empty picture storage buffer, the DPB fullness is incremented by one, and the current picture is marked as "used for short-term reference".

## C.4 Bitstream conformance

A bitstream of coded data conforming to this Specification shall fulfil all requirements specified in this subclause.

The bitstream shall be constructed according to the syntax, semantics, and constraints specified in this Specification outside of this annex.

The first coded picture in a bitstream shall be an IRAP picture, i.e. an IDR picture, a CRA picture or a BLA picture.

The bitstream is tested by the HRD for conformance as specified in subclause C.1.

For each current picture, let the variables maxPicOrderCnt and minPicOrderCnt be set equal to the maximum and the minimum, respectively, of the PicOrderCntVal values of the following pictures:

– The current picture.

– The previous picture in decoding order that has TemporalId equal to 0 and that is not a RASL picture, a RADL picture, or a sub-layer non-reference picture.

– The short-term reference pictures in the RPS of the current picture.

– All pictures n that have PicOutputFlag equal to 1, AuCpbRemovalTime[ n ] less than AuCpbRemovalTime[ currPic ], and DpbOutputTime[ n ] greater than or equal to AuCpbRemovalTime[ currPic ], where currPic is the current picture.

All of the following conditions shall be fulfilled for each of the bitstream conformance tests:

1. For each access unit n, with n greater than 0, associated with a buffering period SEI message, let the variable deltaTime90k[ n ] be specified as follows:

   $$\text{deltaTime90k[ n ] = 90000 * ( AuNominalRemovalTime[ n ]} - \text{AuFinalArrivalTime[ n} - \text{1 ] )} \qquad \text{(C-18)}$$

   The value of InitCpbRemovalDelay[ SchedSelIdx ] is constrained as follows:

   – If cbr_flag[ SchedSelIdx ] is equal to 0, the following condition shall be true:

   $$\text{InitCpbRemovalDelay[ SchedSelIdx ]} <= \text{Ceil( deltaTime90k[ n ] )} \qquad \text{(C-19)}$$

   – Otherwise (cbr_flag[ SchedSelIdx ] is equal to 1), the following condition shall be true:

   $$\text{Floor( deltaTime90k[ n ] )} <= \text{InitCpbRemovalDelay[ SchedSelIdx ]} <= \text{Ceil( deltaTime90k[ n ] )} \qquad \text{(C-20)}$$

   NOTE 1 – The exact number of bits in the CPB at the removal time of each picture may depend on which buffering period SEI message is selected to initialize the HRD. Encoders must take this into account to ensure that all specified constraints must be obeyed regardless of which buffering period SEI message is selected to initialize the HRD, as the HRD may be initialized at any one of the buffering period SEI messages.

2. A CPB overflow is specified as the condition in which the total number of bits in the CPB is greater than the CPB size. The CPB shall never overflow.

3. A CPB underflow is specified as the condition in which the nominal CPB removal time of decoding unit m DuNominalRemovalTime( m ) is less than the final CPB arrival time of decoding unit m DuFinalArrivalTime( m ) for at least one value of m. When low_delay_hrd_flag[ HighestTid ] is equal to 0, the CPB shall never underflow.

4. When SubPicHrdFlag is equal to 1, low_delay_hrd_flag[ HighestTid ] is equal to 1, and the nominal removal time of a decoding unit m of access unit n is less than the final CPB arrival time of decoding unit m (i.e. DuNominalRemovalTime[ m ] < DuFinalArrivalTime[ m ]), the nominal removal time of access unit n shall be less than the final CPB arrival time of access unit n (i.e. AuNominalRemovalTime[ n ] < AuFinalArrivalTime[ n ]).

5. The nominal removal times of pictures from the CPB (starting from the second picture in decoding order) shall satisfy the constraints on AuNominalRemovalTime[ n ] and AuCpbRemovalTime[ n ] expressed in subclauses A.4.1 through A.4.2.

6. For each current picture, after invocation of the process for removal of pictures from the DPB as specified in subclause C.3.2, the number of decoded pictures in the DPB, including all pictures n that are marked as "used for reference", or that have PicOutputFlag equal to 1 and AuCpbRemovalTime[ n ] less than AuCpbRemovalTime[ currPic ], where currPic is the current picture, shall be less than or equal to sps_max_dec_pic_buffering_minus1[ HighestTid ].

7. All reference pictures shall be present in the DPB when needed for prediction. Each picture that has PicOutputFlag equal to 1 shall be present in the DPB at its DPB output time unless it is removed from the DPB before its output time by one of the processes specified in subclause C.3.

8. For each current picture, the value of maxPicOrderCnt − minPicOrderCnt shall be less than MaxPicOrderCntLsb / 2.

9. The value of DpbOutputInterval[ n ] as given by Equation C-17, which is the difference between the output time of a picture and that of the first picture following it in output order and having PicOutputFlag equal to 1, shall satisfy the constraint expressed in subclause A.4.1 for the profile, tier and level specified in the bitstream using the decoding process specified in clauses 2 through 10.

10. For each current picture, when sub_pic_cpb_params_in_pic_timing_sei_flag is equal to 1, let tmpCpbRemovalDelaySum be derived as follows:

```
tmpCpbRemovalDelaySum = 0
for( i = 0; i < num_decoding_units_minus1; i++ )                              (C-21)
    tmpCpbRemovalDelaySum += du_cpb_removal_delay_increment_minus1[ i ] + 1
```

The value of ClockSubTick * tmpCpbRemovalDelaySum shall be equal to the difference between the nominal CPB removal time of the current access unit and the nominal CPB removal time of the first decoding unit in the current access unit in decoding order.

## C.5 Decoder conformance

### C.5.1 General

A decoder conforming to this Specification shall fulfil all requirements specified in this subclause.

A decoder claiming conformance to a specific profile, tier and level shall be able to successfully decode all bitstreams that conform to the bitstream conformance requirements specified in subclause C.4, in the manner specified in Annex A, provided that all VPSs, SPSs and PPSs referred to in the VCL NAL units, and appropriate buffering period and picture timing SEI messages are conveyed to the decoder, in a timely manner, either in the bitstream (by non-VCL NAL units), or by external means not specified in this Specification.

When a bitstream contains syntax elements that have values that are specified as reserved and it is specified that decoders shall ignore values of the syntax elements or NAL units containing the syntax elements having the reserved values, and the bitstream is otherwise conforming to this Specification, a conforming decoder shall decode the bitstream in the same manner as it would decode a conforming bitstream and shall ignore the syntax elements or the NAL units containing the syntax elements having the reserved values as specified.

There are two types of conformance that can be claimed by a decoder: output timing conformance and output order conformance.

To check conformance of a decoder, test bitstreams conforming to the claimed profile, tier and level, as specified in subclause C.4 are delivered by a hypothetical stream scheduler (HSS) both to the HRD and to the decoder under test (DUT). All cropped decoded pictures output by the HRD shall also be output by the DUT, each cropped decoded picture output by the DUT shall be a picture with PicOutputFlag equal to 1, and, for each such cropped decoded picture output by the DUT, the values of all samples that are output shall be equal to the values of the samples produced by the specified decoding process.

For output timing decoder conformance, the HSS operates as described above, with delivery schedules selected only from the subset of values of SchedSelIdx for which the bit rate and CPB size are restricted as specified in Annex A for the specified profile, tier and level, or with "interpolated" delivery schedules as specified below for which the bit rate and CPB size are restricted as specified in Annex A. The same delivery schedule is used for both the HRD and the DUT.

When the HRD parameters and the buffering period SEI messages are present with cpb_cnt_minus1[ HighestTid ] greater than 0, the decoder shall be capable of decoding the bitstream as delivered from the HSS operating using an "interpolated" delivery schedule specified as having peak bit rate r, CPB size c( r ), and initial CPB removal delay ( f( r ) ÷ r ) as follows:

$$\alpha = ( r - \text{BitRate}[\ \text{SchedSelIdx} - 1\ ] ) \div ( \text{BitRate}[\ \text{SchedSelIdx}\ ] - \text{BitRate}[\ \text{SchedSelIdx} - 1\ ] ), \quad \text{(C-22)}$$

$$c( r ) = \alpha * \text{CpbSize}[\ \text{SchedSelIdx}\ ] + ( 1 - \alpha ) * \text{CpbSize}[\ \text{SchedSelIdx} - 1\ ], \quad \text{(C-23)}$$

$$f( r ) = \alpha * \text{InitCpbRemovalDelay}[\ \text{SchedSelIdx}\ ] * \text{BitRate}[\ \text{SchedSelIdx}\ ] + ( 1 - \alpha ) * \text{InitCpbRemovalDelay}[\ \text{SchedSelIdx} - 1\ ] * \text{BitRate}[\ \text{SchedSelIdx} - 1\ ] \quad \text{(C-24)}$$

for any SchedSelIdx > 0 and r such that BitRate[ SchedSelIdx − 1 ] <= r <= BitRate[ SchedSelIdx ] such that r and c( r ) are within the limits as specified in Annex A for the maximum bit rate and buffer size for the specified profile, tier and level.

NOTE 1 – InitCpbRemovalDelay[ SchedSelIdx ] can be different from one buffering period to another and have to be re-calculated.

For output timing decoder conformance, an HRD as described above is used and the timing (relative to the delivery time of the first bit) of picture output is the same for both the HRD and the DUT up to a fixed delay.

For output order decoder conformance, the following applies:

– The HSS delivers the bitstream BitstreamToDecode to the DUT "by demand" from the DUT, meaning that the HSS delivers bits (in decoding order) only when the DUT requires more bits to proceed with its processing.

  NOTE 2 – This means that for this test, the coded picture buffer of the DUT could be as small as the size of the largest decoding unit.

– A modified HRD as described below is used, and the HSS delivers the bitstream to the HRD by one of the schedules specified in the bitstream BitstreamToDecode such that the bit rate and CPB size are restricted as specified in Annex A. The order of pictures output shall be the same for both the HRD and the DUT.

– The HRD CPB size is given by CpbSize[ SchedSelIdx ] as specified in subclause E.2.3, where SchedSelIdx and the HRD parameters are selected as specified in subclause C.1. The DPB size is given by sps_max_dec_pic_buffering_minus1[ HighestTid ] + 1. Removal time from the CPB for the HRD is the final bit arrival time and decoding is immediate. The operation of the DPB of this HRD is as described in subclauses C.5.2 through C.5.2.3.

### C.5.2 Operation of the output order DPB

#### C.5.2.1 General

The decoded picture buffer contains picture storage buffers. Each of the picture storage buffers contains a decoded picture that is marked as "used for reference" or is held for future output. The process for output and removal of pictures from the DPB as specified in subclause C.5.2.2 is invoked, followed by the invocation of the process for picture decoding, marking, additional bumping, and storage as specified in subclause C.5.2.3. The "bumping" process is specified in subclause C.5.2.4 and is invoked as specified in subclauses C.5.2.2 and C.5.2.3.

#### C.5.2.2 Output and removal of pictures from the DPB

The output and removal of pictures from the DPB before the decoding of the current picture (but after parsing the slice header of the first slice of the current picture) happens instantaneously when the first decoding unit of the access unit containing the current picture is removed from the CPB and proceeds as follows:

– The decoding process for RPS as specified in subclause 8.3.2 is invoked.

– If the current picture is an IRAP picture with NoRaslOutputFlag equal to 1 that is not picture 0, the following ordered steps are applied:

  1. The variable NoOutputOfPriorPicsFlag is derived for the decoder under test as follows:

     – If the current picture is a CRA picture, NoOutputOfPriorPicsFlag is set equal to 1 (regardless of the value of no_output_of_prior_pics_flag).

     – Otherwise, if the value of pic_width_in_luma_samples, pic_height_in_luma_samples, or sps_max_dec_pic_buffering_minus1[ HighestTid ] derived from the active SPS is different from the value of pic_width_in_luma_samples, pic_height_in_luma_samples, or sps_max_dec_pic_buffering_minus1[ HighestTid ], respectively, derived from the SPS active for the preceding picture, NoOutputOfPriorPicsFlag may (but should not) be set to 1 by the decoder under test, regardless of the value of no_output_of_prior_pics_flag.

NOTE – Although setting NoOutputOfPriorPicsFlag equal to no_output_of_prior_pics_flag is preferred under these conditions, the decoder under test is allowed to set NoOutputOfPriorPicsFlag to 1 in this case.

– Otherwise, NoOutputOfPriorPicsFlag is set equal to no_output_of_prior_pics_flag.

2. The value of NoOutputOfPriorPicsFlag derived for the decoder under test is applied for the HRD as follows:

   – If NoOutputOfPriorPicsFlag is equal to 1, all picture storage buffers in the DPB are emptied without output of the pictures they contain, and the DPB fullness is set equal to 0.

   – Otherwise (NoOutputOfPriorPicsFlag is equal to 0), all picture storage buffers containing a picture that is marked as "not needed for output" and "unused for reference" are emptied (without output), and all non-empty picture storage buffers in the DPB are emptied by repeatedly invoking the "bumping" process specified in subclause C.5.2.4, and the DPB fullness is set equal to 0.

– Otherwise (the current picture is not an IRAP picture with NoRaslOutputFlag equal to 1), all picture storage buffers containing a picture which are marked as "not needed for output" and "unused for reference" are emptied (without output). For each picture storage buffer that is emptied, the DPB fullness is decremented by one. When one or more of the following conditions are true, the "bumping" process specified in subclause C.5.2.4 is invoked repeatedly while further decrementing the DPB fullness by one for each additional picture storage buffer that is emptied, until none of the following conditions are true:

  – The number of pictures in the DPB that are marked as "needed for output" is greater than sps_max_num_reorder_pics[ HighestTid ].

  – sps_max_latency_increase_plus1[ HighestTid ] is not equal to 0 and there is at least one picture in the DPB that is marked as "needed for output" for which the associated variable PicLatencyCount is greater than or equal to SpsMaxLatencyPictures[ HighestTid ].

  – The number of pictures in the DPB is greater than or equal to sps_max_dec_pic_buffering_minus1[ HighestTid ] + 1.

### C.5.2.3 Picture decoding, marking, additional bumping, and storage

The processes specified in this subclause happen instantaneously when the last decoding unit of access unit n containing the current picture is removed from the CPB.

For each picture in the DPB that is marked as "needed for output", the associated variable PicLatencyCount is set equal to PicLatencyCount + 1.

The current picture is considered as decoded after the last decoding unit of the picture is decoded. The current decoded picture is stored in an empty picture storage buffer in the DPB, and the following applies:

– If the current decoded picture has PicOutputFlag equal to 1, it is marked as "needed for output" and its associated variable PicLatencyCount is set equal to 0.

– Otherwise (the current decoded picture has PicOutputFlag equal to 0), it is marked as "not needed for output".

The current decoded picture is marked as "used for short-term reference".

When one or more of the following conditions are true, the "bumping" process specified in subclause C.5.2.4 is invoked repeatedly until none of the following conditions are true:

– The number of pictures in the DPB that are marked as "needed for output" is greater than sps_max_num_reorder_pics[ HighestTid ].

– sps_max_latency_increase_plus1[ HighestTid ] is not equal to 0 and there is at least one picture in the DPB that is marked as "needed for output" for which the associated variable PicLatencyCount that is greater than or equal to SpsMaxLatencyPictures[ HighestTid ].

### C.5.2.4 "Bumping" process

The "bumping" process consists of the following ordered steps:

1. The picture that is first for output is selected as the one having the smallest value of PicOrderCntVal of all pictures in the DPB marked as "needed for output".

2. The picture is cropped, using the conformance cropping window specified in the active SPS for the picture, the cropped picture is output, and the picture is marked as "not needed for output".

3. When the picture storage buffer that included the picture that was cropped and output contains a picture marked as "unused for reference", the picture storage buffer is emptied.

# Annex D

# Supplemental enhancement information

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

## D.1 General

This annex specifies syntax and semantics for SEI message payloads.

SEI messages assist in processes related to decoding, display or other purposes. However, SEI messages are not required for constructing the luma or chroma samples by the decoding process. Conforming decoders are not required to process this information for output order conformance to this Specification (see Annex C for the specification of conformance). Some SEI message information is required to check bitstream conformance and for output timing decoder conformance.

In subclause C.5.2, specification for presence of SEI messages are also satisfied when those messages (or some subset of them) are conveyed to decoders (or to the HRD) by other means not specified in this Specification. When present in the bitstream, SEI messages shall obey the syntax and semantics specified in subclause 7.3.5 and this annex. When the content of an SEI message is conveyed for the application by some means other than presence within the bitstream, the representation of the content of the SEI message is not required to use the same syntax specified in this annex. For the purpose of counting bits, only the appropriate bits that are actually present in the bitstream are counted.

## D.2 SEI payload syntax

### D.2.1 General SEI message syntax

| sei_payload( payloadType, payloadSize ) { | **Descriptor** |
|---|---|
|   if( nal_unit_type = = PREFIX_SEI_NUT ) | |
|     if( payloadType = = 0 ) | |
|       buffering_period( payloadSize ) | |
|     else if( payloadType = = 1 ) | |
|       pic_timing( payloadSize ) | |
|     else if( payloadType = = 2 ) | |
|       pan_scan_rect( payloadSize ) | |
|     else if( payloadType = = 3 ) | |
|       filler_payload( payloadSize ) | |
|     else if( payloadType = = 4 ) | |
|       user_data_registered_itu_t_t35( payloadSize ) | |
|     else if( payloadType = = 5 ) | |
|       user_data_unregistered( payloadSize ) | |
|     else if( payloadType = = 6 ) | |
|       recovery_point( payloadSize ) | |
|     else if( payloadType = = 9 ) | |
|       scene_info( payloadSize ) | |
|     else if( payloadType = = 15 ) | |
|       picture_snapshot( payloadSize ) | |
|     else if( payloadType = = 16 ) | |
|       progressive_refinement_segment_start( payloadSize ) | |
|     else if( payloadType = = 17 ) | |
|       progressive_refinement_segment_end( payloadSize ) | |
|     else if( payloadType = = 19 ) | |
|       film_grain_characteristics( payloadSize ) | |
|     else if( payloadType = = 22 ) | |
|       post_filter_hint( payloadSize ) | |
|     else if( payloadType = = 23 ) | |
|       tone_mapping_info( payloadSize ) | |
|     else if( payloadType = = 45 ) | |
|       frame_packing_arrangement( payloadSize ) | |
|     else if( payloadType = = 47 ) | |
|       display_orientation( payloadSize ) | |
|     else if( payloadType = = 128 ) | |
|       structure_of_pictures_info( payloadSize ) | |
|     else if( payloadType = = 129 ) | |
|       active_parameter_sets( payloadSize ) | |
|     else if( payloadType = = 130 ) | |
|       decoding_unit_info( payloadSize ) | |
|     else if( payloadType = = 131 ) | |
|       temporal_sub_layer_zero_index( payloadSize ) | |
|     else if( payloadType = = 133 ) | |
|       scalable_nesting( payloadSize ) | |
|     else if( payloadType = = 134 ) | |

| | |
|---|---|
|       region_refresh_info( payloadSize ) | |
|     else | |
|       reserved_sei_message( payloadSize ) | |
|   else /* nal_unit_type = = SUFFIX_SEI_NUT */ | |
|     if( payloadType = = 3 ) | |
|       filler_payload( payloadSize ) | |
|     else if( payloadType = = 4 ) | |
|       user_data_registered_itu_t_t35( payloadSize ) | |
|     else if( payloadType = = 5 ) | |
|       user_data_unregistered( payloadSize ) | |
|     else if( payloadType = = 17 ) | |
|       progressive_refinement_segment_end( payloadSize ) | |
|     else if( payloadType = = 22 ) | |
|       post_filter_hint( payloadSize ) | |
|     else if( payloadType = = 132 ) | |
|       decoded_picture_hash( payloadSize ) | |
|     else | |
|       reserved_sei_message( payloadSize ) | |
|   if( more_data_in_payload( ) ) { | |
|     if( payload_extension_present( ) ) | |
|       **reserved_payload_extension_data** | u(v) |
|     **payload_bit_equal_to_one** /* equal to 1 */ | f(1) |
|     while( !byte_aligned( ) ) | |
|       **payload_bit_equal_to_zero** /* equal to 0 */ | f(1) |
|   } | |
| } | |

### D.2.2 Buffering period SEI message syntax

| buffering_period( payloadSize ) { | **Descriptor** |
|---|---|
|     **bp_seq_parameter_set_id** | ue(v) |
|     if( !sub_pic_hrd_params_present_flag ) | |
|         **irap_cpb_params_present_flag** | u(1) |
|     if( irap_cpb_params_present_flag ) { | |
|         **cpb_delay_offset** | u(v) |
|         **dpb_delay_offset** | u(v) |
|     } | |
|     **concatenation_flag** | u(1) |
|     **au_cpb_removal_delay_delta_minus1** | u(v) |
|     if( NalHrdBpPresentFlag ) { | |
|         for( i = 0; i <= CpbCnt; i++ ) { | |
|             **nal_initial_cpb_removal_delay**[ i ] | u(v) |
|             **nal_initial_cpb_removal_offset**[ i ] | u(v) |
|             if( sub_pic_hrd_params_present_flag \|\| irap_cpb_params_present_flag ) { | |
|                 **nal_initial_alt_cpb_removal_delay**[ i ] | u(v) |
|                 **nal_initial_alt_cpb_removal_offset**[ i ] | u(v) |
|             } | |
|         } | |
|     } | |
|     if( VclHrdBpPresentFlag ) { | |
|         for( i = 0; i <= CpbCnt; i++ ) { | |
|             **vcl_initial_cpb_removal_delay**[ i ] | u(v) |
|             **vcl_initial_cpb_removal_offset**[ i ] | u(v) |
|             if( sub_pic_hrd_params_present_flag \|\| irap_cpb_params_present_flag) { | |
|                 **vcl_initial_alt_cpb_removal_delay**[ i ] | u(v) |
|                 **vcl_initial_alt_cpb_removal_offset**[ i ] | u(v) |
|             } | |
|         } | |
|     } | |
| } | |

### D.2.3 Picture timing SEI message syntax

| pic_timing( payloadSize ) { | **Descriptor** |
|---|---|
|   if( frame_field_info_present_flag ) { | |
|     **pic_struct** | u(4) |
|     **source_scan_type** | u(2) |
|     **duplicate_flag** | u(1) |
|   } | |
|   if( CpbDpbDelaysPresentFlag ) { | |
|     **au_cpb_removal_delay_minus1** | u(v) |
|     **pic_dpb_output_delay** | u(v) |
|     if( sub_pic_hrd_params_present_flag ) | |
|       **pic_dpb_output_du_delay** | u(v) |
|     if( sub_pic_hrd_params_present_flag && sub_pic_cpb_params_in_pic_timing_sei_flag ) { | |
|       **num_decoding_units_minus1** | ue(v) |
|       **du_common_cpb_removal_delay_flag** | u(1) |
|       if( du_common_cpb_removal_delay_flag ) | |
|         **du_common_cpb_removal_delay_increment_minus1** | u(v) |
|       for( i = 0; i <= num_decoding_units_minus1; i++ ) { | |
|         **num_nalus_in_du_minus1**[ i ] | ue(v) |
|         if( !du_common_cpb_removal_delay_flag && i < num_decoding_units_minus1 ) | |
|           **du_cpb_removal_delay_increment_minus1**[ i ] | u(v) |
|       } | |
|     } | |
|   } | |
| } | |

### D.2.4 Pan-scan rectangle SEI message syntax

| pan_scan_rect( payloadSize ) { | **Descriptor** |
|---|---|
|   **pan_scan_rect_id** | ue(v) |
|   **pan_scan_rect_cancel_flag** | u(1) |
|   if( !pan_scan_rect_cancel_flag ) { | |
|     **pan_scan_cnt_minus1** | ue(v) |
|     for( i = 0; i <= pan_scan_cnt_minus1; i++ ) { | |
|       **pan_scan_rect_left_offset**[ i ] | se(v) |
|       **pan_scan_rect_right_offset**[ i ] | se(v) |
|       **pan_scan_rect_top_offset**[ i ] | se(v) |
|       **pan_scan_rect_bottom_offset**[ i ] | se(v) |
|     } | |
|     **pan_scan_rect_persistence_flag** | u(1) |
|   } | |
| } | |

### D.2.5 Filler payload SEI message syntax

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

### D.2.6 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 ) | |
| } | |

### D.2.7 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) |
| } | |

### D.2.8 Recovery point SEI message syntax

| recovery_point( payloadSize ) { | **Descriptor** |
|---|---|
|   **recovery_poc_cnt** | se(v) |
|   **exact_match_flag** | u(1) |
|   **broken_link_flag** | u(1) |
| } | |

### D.2.9 Scene information SEI message syntax

| scene_info( payloadSize ) { | **Descriptor** |
|---|---|
| **scene_info_present_flag** | u(1) |
| if( scene_info_present_flag ) { | |
| **prev_scene_id_valid_flag** | u(1) |
| **scene_id** | ue(v) |
| **scene_transition_type** | ue(v) |
| if( scene_transition_type > 3 ) | |
| **second_scene_id** | ue(v) |
| } | |
| } | |

### D.2.10 Picture snapshot SEI message syntax

| picture_snapshot( payloadSize ) { | **Descriptor** |
|---|---|
| **snapshot_id** | ue(v) |
| } | |

### D.2.11 Progressive refinement segment start SEI message syntax

| progressive_refinement_segment_start( payloadSize ) { | **Descriptor** |
|---|---|
| **progressive_refinement_id** | ue(v) |
| **pic_order_cnt_delta** | ue(v) |
| } | |

### D.2.12 Progressive refinement segment end SEI message syntax

| progressive_refinement_segment_end( payloadSize ) { | **Descriptor** |
|---|---|
| **progressive_refinement_id** | ue(v) |
| } | |

### D.2.13 Film grain characteristics SEI message syntax

| film_grain_characteristics( payloadSize ) { | **Descriptor** |
|---|---|
| **film_grain_characteristics_cancel_flag** | u(1) |
| if( !film_grain_characteristics_cancel_flag ) { | |
| **film_grain_model_id** | u(2) |
| **separate_colour_description_present_flag** | u(1) |
| if( separate_colour_description_present_flag ) { | |
| **film_grain_bit_depth_luma_minus8** | u(3) |
| **film_grain_bit_depth_chroma_minus8** | u(3) |
| **film_grain_full_range_flag** | u(1) |
| **film_grain_colour_primaries** | u(8) |
| **film_grain_transfer_characteristics** | u(8) |
| **film_grain_matrix_coeffs** | u(8) |
| } | |
| **blending_mode_id** | u(2) |
| **log2_scale_factor** | u(4) |
| for( c = 0; c < 3; c++ ) | |
| **comp_model_present_flag**[ c ] | u(1) |
| for( c = 0; c < 3; c++ ) | |
| if( comp_model_present_flag[ c ] ) { | |
| **num_intensity_intervals_minus1[ c ]** | u(8) |
| **num_model_values_minus1[ c ]** | u(3) |
| for( i = 0; i <= num_intensity_intervals_minus1[ c ]; i++ ) { | |
| **intensity_interval_lower_bound[ c ][ i ]** | u(8) |
| **intensity_interval_upper_bound[ c ][ i ]** | u(8) |
| for( j = 0; j <= num_model_values_minus1[ c ]; j++ ) | |
| **comp_model_value**[ c ][ i ][ j ] | se(v) |
| } | |
| } | |
| **film_grain_characteristics_persistence_flag** | u(1) |
| } | |
| } | |

### D.2.14 Post-filter hint SEI message syntax

| post_filter_hint( payloadSize ) { | **Descriptor** |
|---|---|
| **filter_hint_size_y** | ue(v) |
| **filter_hint_size_x** | ue(v) |
| **filter_hint_type** | u(2) |
| for( cIdx = 0; cIdx < ( chroma_format_idc == 0 ? 1 : 3 ); cIdx++ ) | |
| for( cy = 0; cy < filter_hint_size_y; cy ++ ) | |
| for( cx = 0; cx < filter_hint_size_x; cx ++ ) | |
| **filter_hint_value**[ cIdx ][ cy ][ cx ] | se(v) |
| } | |

### D.2.15 Tone mapping information SEI message syntax

| tone_mapping_info( payloadSize ) { | **Descriptor** |
|---|---|
| **tone_map_id** | ue(v) |
| **tone_map_cancel_flag** | u(1) |
| if( !tone_map_cancel_flag ) { | |
| **tone_map_persistence_flag** | u(1) |
| **coded_data_bit_depth** | u(8) |
| **target_bit_depth** | u(8) |
| **tone_map_model_id** | ue(v) |
| if( tone_map_model_id  = =  0 ) { | |
| **min_value** | u(32) |
| **max_value** | u(32) |
| } else if( tone_map_model_id  = =  1 ) { | |
| **sigmoid_midpoint** | u(32) |
| **sigmoid_width** | u(32) |
| } else if( tone_map_model_id  = =  2 ) | |
| for( i = 0; i < ( 1  <<  target_bit_depth ); i++ ) | |
| **start_of_coded_interval**[ i ] | u(v) |
| else if( tone_map_model_id  = =  3 ) { | |
| **num_pivots** | u(16) |
| for( i = 0; i < num_pivots; i++ ) { | |
| **coded_pivot_value**[ i ] | u(v) |
| **target_pivot_value**[ i ] | u(v) |
| } | |
| } else if( tone_map_model_id  = =  4 ) { | |
| **camera_iso_speed_idc** | u(8) |
| if( camera_iso_speed_idc  = =  EXTENDED_ISO ) | |
| **camera_iso_speed_value** | u(32) |
| **exposure_index_idc** | u(8) |
| if( exposure_index_idc  = =  EXTENDED_ISO ) | |
| **exposure_index_value** | u(32) |
| **exposure_compensation_value_sign_flag** | u(1) |
| **exposure_compensation_value_numerator** | u(16) |
| **exposure_compensation_value_denom_idc** | u(16) |
| **ref_screen_luminance_white** | u(32) |
| **extended_range_white_level** | u(32) |
| **nominal_black_level_code_value** | u(16) |
| **nominal_white_level_code_value** | u(16) |
| **extended_white_level_code_value** | u(16) |
| } | |
| } | |
| } | |

### D.2.16 Frame packing arrangement SEI message syntax

| frame_packing_arrangement( payloadSize ) { | **Descriptor** |
|---|---|
|  **frame_packing_arrangement_id** | ue(v) |
|  **frame_packing_arrangement_cancel_flag** | u(1) |
|  if( !frame_packing_arrangement_cancel_flag ) { | |
|   **frame_packing_arrangement_type** | u(7) |
|   **quincunx_sampling_flag** | u(1) |
|   **content_interpretation_type** | u(6) |
|   **spatial_flipping_flag** | u(1) |
|   **frame0_flipped_flag** | u(1) |
|   **field_views_flag** | u(1) |
|   **current_frame_is_frame0_flag** | u(1) |
|   **frame0_self_contained_flag** | u(1) |
|   **frame1_self_contained_flag** | u(1) |
|   if( !quincunx_sampling_flag && frame_packing_arrangement_type != 5 ) { | |
|    **frame0_grid_position_x** | u(4) |
|    **frame0_grid_position_y** | u(4) |
|    **frame1_grid_position_x** | u(4) |
|    **frame1_grid_position_y** | u(4) |
|   } | |
|   **frame_packing_arrangement_reserved_byte** | u(8) |
|   **frame_packing_arrangement_persistence_flag** | u(1) |
|  } | |
|  **upsampled_aspect_ratio_flag** | u(1) |
| } | |

### D.2.17 Display orientation SEI message syntax

| display_orientation( payloadSize ) { | **Descriptor** |
|---|---|
|  **display_orientation_cancel_flag** | u(1) |
|  if( !display_orientation_cancel_flag ) { | |
|   **hor_flip** | u(1) |
|   **ver_flip** | u(1) |
|   **anticlockwise_rotation** | u(16) |
|   **display_orientation_persistence_flag** | u(1) |
|  } | |
| } | |

### D.2.18 Structure of pictures information SEI message syntax

| structure_of_pictures_info( payloadSize ) { | **Descriptor** |
|---|---|
|   **sop_seq_parameter_set_id** | ue(v) |
|   **num_entries_in_sop_minus1** | ue(v) |
|   for( i = 0; i <= num_entries_in_sop_minus1; i++ ) { | |
|     **sop_vcl_nut**[ i ] | u(6) |
|     **sop_temporal_id**[ i ] | u(3) |
|     if( sop_vcl_nut[ i ] != IDR_W_RADL && sop_vcl_nut[ i ] != IDR_N_LP ) | |
|       **sop_short_term_rps_idx**[ i ] | ue(v) |
|     if( i > 0 ) | |
|       **sop_poc_delta**[ i ] | se(v) |
|   } | |
| } | |

### D.2.19 Decoded picture hash SEI message syntax

| decoded_picture_hash( payloadSize ) { | **Descriptor** |
|---|---|
|   **hash_type** | u(8) |
|   for( cIdx = 0; cIdx < ( chroma_format_idc = = 0 ? 1 : 3 ); cIdx++ ) | |
|     if( hash_type = = 0 ) | |
|       for( i = 0; i < 16; i++) | |
|         **picture_md5**[ cIdx ][ i ] | b(8) |
|     else if( hash_type = = 1 ) | |
|       **picture_crc**[ cIdx ] | u(16) |
|     else if( hash_type = = 2 ) | |
|       **picture_checksum**[ cIdx ] | u(32) |
| } | |

### D.2.20 Active parameter sets SEI message syntax

| active_parameter_sets( payloadSize ) { | **Descriptor** |
|---|---|
|   **active_video_parameter_set_id** | u(4) |
|   **self_contained_cvs_flag** | u(1) |
|   **no_parameter_set_update_flag** | u(1) |
|   **num_sps_ids_minus1** | ue(v) |
|   for( i = 0; i <= num_sps_ids_minus1; i++ ) | |
|     **active_seq_parameter_set_id**[ i ] | ue(v) |
| } | |

### D.2.21 Decoding unit information SEI message syntax

| decoding_unit_info( payloadSize ) { | **Descriptor** |
|---|---|
|  **decoding_unit_idx** | ue(v) |
|  if( !sub_pic_cpb_params_in_pic_timing_sei_flag ) | |
|   **du_spt_cpb_removal_delay_increment** | u(v) |
|  **dpb_output_du_delay_present_flag** | u(1) |
|  if( dpb_output_du_delay_present_flag ) | |
|   **pic_spt_dpb_output_du_delay** | u(v) |
| } | |

### D.2.22 Temporal sub-layer zero index SEI message syntax

| temporal_sub_layer_zero_index( payloadSize ) { | **Descriptor** |
|---|---|
|  **temporal_sub_layer_zero_idx** | u(8) |
|  **irap_pic_id** | u(8) |
| } | |

### D.2.23 Scalable nesting SEI message syntax

| scalable_nesting( payloadSize ) { | **Descriptor** |
|---|---|
|  **bitstream_subset_flag** | u(1) |
|  **nesting_op_flag** | u(1) |
|  if( nesting_op_flag ) { | |
|   **default_op_flag** | u(1) |
|   **nesting_num_ops_minus1** | ue(v) |
|   for( i = default_op_flag; i <= nesting_num_ops_minus1; i++ ) { | |
|    **nesting_max_temporal_id_plus1**[ i ] | u(3) |
|    **nesting_op_idx**[ i ] | ue(v) |
|   } | |
|  } else { | |
|   **all_layers_flag** | u(1) |
|   if( !all_layers_flag ) { | |
|    **nesting_no_op_max_temporal_id_plus1** | u(3) |
|    **nesting_num_layers_minus1** | ue(v) |
|    for( i = 0; i <= nesting_num_layers_minus1; i++ ) | |
|     **nesting_layer_id**[ i ] | u(6) |
|   } | |
|  } | |
|  while( !byte_aligned( ) ) | |
|   **nesting_zero_bit** /* equal to 0 */ | u(1) |
|  do | |
|   sei_message( ) | |
|  while( more_rbsp_data( ) ) | |
| } | |

### D.2.24 Region refresh information SEI message syntax

| region_refresh_info( payloadSize ) { | **Descriptor** |
|---|---|
| **refreshed_region_flag** | u(1) |
| } | |

### D.2.25 Reserved SEI message syntax

| reserved_sei_message( payloadSize ) { | **Descriptor** |
|---|---|
| for( i = 0; i < payloadSize; i++ ) | |
| **reserved_sei_message_payload_byte** | b(8) |
| } | |

## D.3 SEI payload semantics

### D.3.1 General SEI payload semantics

**reserved_payload_extension_data** shall not be present in bitstreams conforming to this version of this Specification. However, decoders conforming to this version of this Specification shall ignore the presence and value of reserved_payload_extension_data. When present, the length, in bits, of reserved_payload_extension_data is equal to 8 * payloadSize − nEarlierBits − nPayloadZeroBits − 1, where nEarlierBits is the number of bits in the sei_payload( ) syntax structure that precede the reserved_payload_extension_data syntax element, and nPayloadZeroBits is the number of payload_bit_equal_to_zero syntax elements at the end of the sei_payload( ) syntax structure.

**payload_bit_equal_to_one** shall be equal to 1.

**payload_bit_equal_to_zero** shall be equal to 0.

NOTE 1 – SEI messages with the same value of payloadType are conceptually the same SEI message regardless of whether they are contained in prefix or suffix SEI NAL units.

NOTE 2 – For SEI messages with payloadType in the range of 0 to 47, inclusive, that are specified in this Specification, the payloadType values are aligned with similar SEI messages specified in Rec. ITU-T H.264 | ISO/IEC 14496-10.

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

NOTE 3 – Persistence information for SEI messages is informatively summarized in Table D-1.