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Infrastructure of audiovisual services – Coding of moving
video

**Advanced video coding for generic audiovisual
services**

ITU-T Recommendation H.264

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ITU-T H-SERIES RECOMMENDATIONS
AUDIOVISUAL AND MULTIMEDIA SYSTEMS

CHARACTERISTICS OF VISUAL TELEPHONE SYSTEMS	H.100–H.199
INFRASTRUCTURE OF AUDIOVISUAL SERVICES	
General	H.200–H.219
Transmission multiplexing and synchronization	H.220–H.229
Systems aspects	H.230–H.239
Communication procedures	H.240–H.259
Coding of moving video	H.260–H.279
Related systems aspects	H.280–H.299
Systems and terminal equipment for audiovisual services	H.300–H.349
Directory services architecture for audiovisual and multimedia services	H.350–H.359
Quality of service architecture for audiovisual and multimedia services	H.360–H.369
Supplementary services for multimedia	H.450–H.499
MOBILITY AND COLLABORATION PROCEDURES	
Overview of Mobility and Collaboration, definitions, protocols and procedures	H.500–H.509
Mobility for H-Series multimedia systems and services	H.510–H.519
Mobile multimedia collaboration applications and services	H.520–H.529
Security for mobile multimedia systems and services	H.530–H.539
Security for mobile multimedia collaboration applications and services	H.540–H.549
Mobility interworking procedures	H.550–H.559
Mobile multimedia collaboration inter-working procedures	H.560–H.569
BROADBAND AND TRIPLE-PLAY MULTIMEDIA SERVICES	
Broadband multimedia services over VDSL	H.610–H.619

For further details, please refer to the list of ITU-T Recommendations.

ITU-T Recommendation H.264

Advanced video coding for generic audiovisual services

Summary

This Recommendation | International Standard represents an evolution of the existing video coding standards (H.261, H.262, and H.263) and it 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 communication. It is also designed to enable the use of the coded video representation in a flexible manner for a wide variety of network environments. 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.

The revision approved 2005-03 contains modifications of the video coding standard to add four new profiles, referred to as the High, High 10, High 4:2:2, and High 4:4:4 profiles, to improve video quality capability and to extend the range of applications addressed by the standard (for example, by including support for a greater range of picture sample precision and higher-resolution chroma formats). Additionally, a definition of new types of supplemental data has been specified to further broaden the applicability of the video coding standard. Finally, a number of corrections to errors in the published text have been included. This revision, in addition to enhancing video coding capability, will serve to maintain technical alignment with the corresponding jointly-developed ISO/IEC 14496-10 standard.

Corrigendum 1 to ITU-T Rec. H.264 corrected and updated various minor aspects to bring the ITU-T version of the text up to date relative to the April 2005 output status approved as a new edition of the corresponding jointly-developed and technically-aligned text ISO/IEC 14496-10. It additionally fixes a number of minor errors and needs for clarification and defines three previously-reserved sample aspect ratio indicators.

This edition includes the text approved 2005-03 and its Corrigendum 1 approved 2005-09.

Source

ITU-T Recommendation H.264 was approved on 1 March 2005 by ITU-T Study Group 16 (2005-2008) under the ITU-T Recommendation A.8 procedure. It includes modifications introduced by H.264 (2005) Cor.1 approved on 13 September 2005 by ITU-T Study Group 16 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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CONTENTS

	Page
Foreword	xiv
0 Introduction	1
0.1 Prologue	1
0.2 Purpose	1
0.3 Applications	1
0.4 Publication and versions of this specification	1
0.5 Profiles and levels	2
0.6 Overview of the design characteristics	2
0.6.1 Predictive coding	3
0.6.2 Coding of progressive and interlaced video	3
0.6.3 Picture partitioning into macroblocks and smaller partitions	3
0.6.4 Spatial redundancy reduction	3
0.7 How to read this specification	3
1 Scope	4
2 Normative references	4
3 Definitions	4
4 Abbreviations	12
5 Conventions	12
5.1 Arithmetic operators	13
5.2 Logical operators	13
5.3 Relational operators	13
5.4 Bit-wise operators	13
5.5 Assignment operators	14
5.6 Range notation	14
5.7 Mathematical functions	14
5.8 Variables, syntax elements, and tables	15
5.9 Text description of logical operations	16
5.10 Processes	17
6 Source, coded, decoded and output data formats, scanning processes, and neighbouring relationships	17
6.1 Bitstream formats	17
6.2 Source, decoded, and output picture formats	17
6.3 Spatial subdivision of pictures and slices	22
6.4 Inverse scanning processes and derivation processes for neighbours	23
6.4.1 Inverse macroblock scanning process	23
6.4.2 Inverse macroblock partition and sub-macroblock partition scanning process	24
6.4.2.1 Inverse macroblock partition scanning process	25
6.4.2.2 Inverse sub-macroblock partition scanning process	25
6.4.3 Inverse 4x4 luma block scanning process	26
6.4.4 Inverse 8x8 luma block scanning process	26
6.4.5 Derivation process of the availability for macroblock addresses	26
6.4.6 Derivation process for neighbouring macroblock addresses and their availability	27
6.4.7 Derivation process for neighbouring macroblock addresses and their availability in MBAFF frames	27
6.4.8 Derivation processes for neighbouring macroblocks, blocks, and partitions	28
6.4.8.1 Derivation process for neighbouring macroblocks	29
6.4.8.2 Derivation process for neighbouring 8x8 luma block	29
6.4.8.3 Derivation process for neighbouring 4x4 luma blocks	30
6.4.8.4 Derivation process for neighbouring 4x4 chroma blocks	30
6.4.8.5 Derivation process for neighbouring partitions	31
6.4.9 Derivation process for neighbouring locations	33
6.4.9.1 Specification for neighbouring locations in fields and non-MBAFF frames	33
6.4.9.2 Specification for neighbouring locations in MBAFF frames	34
7 Syntax and semantics	36
7.1 Method of describing syntax in tabular form	36
7.2 Specification of syntax functions, categories, and descriptors	37
7.3 Syntax in tabular form	38
7.3.1 NAL unit syntax	38
7.3.2 Raw byte sequence payloads and RBSP trailing bits syntax	39
7.3.2.1 Sequence parameter set RBSP syntax	39

7.3.2.1.1	Scaling list syntax	40
7.3.2.1.2	Sequence parameter set extension RBSP syntax	40
7.3.2.2	Picture parameter set RBSP syntax	41
7.3.2.3	Supplemental enhancement information RBSP syntax	42
7.3.2.3.1	Supplemental enhancement information message syntax	42
7.3.2.4	Access unit delimiter RBSP syntax	43
7.3.2.5	End of sequence RBSP syntax	43
7.3.2.6	End of stream RBSP syntax	43
7.3.2.7	Filler data RBSP syntax	43
7.3.2.8	Slice layer without partitioning RBSP syntax	43
7.3.2.9	Slice data partition RBSP syntax	43
7.3.2.9.1	Slice data partition A RBSP syntax	43
7.3.2.9.2	Slice data partition B RBSP syntax	44
7.3.2.9.3	Slice data partition C RBSP syntax	44
7.3.2.10	RBSP slice trailing bits syntax	44
7.3.2.11	RBSP trailing bits syntax	44
7.3.3	Slice header syntax	45
7.3.3.1	Reference picture list reordering syntax	46
7.3.3.2	Prediction weight table syntax	47
7.3.3.3	Decoded reference picture marking syntax	48
7.3.4	Slice data syntax	49
7.3.5	Macroblock layer syntax	50
7.3.5.1	Macroblock prediction syntax	51
7.3.5.2	Sub-macroblock prediction syntax	52
7.3.5.3	Residual data syntax	53
7.3.5.3.1	Residual block CAVLC syntax	54
7.3.5.3.2	Residual block CABAC syntax	55
7.4	<i>Semantics</i>	56
7.4.1	NAL unit semantics	56
7.4.1.1	Encapsulation of an SODB within an RBSP (informative)	58
7.4.1.2	Order of NAL units and association to coded pictures, access units, and video sequences	59
7.4.1.2.1	Order of sequence and picture parameter set RBSPs and their activation	59
7.4.1.2.2	Order of access units and association to coded video sequences	60
7.4.1.2.3	Order of NAL units and coded pictures and association to access units	60
7.4.1.2.4	Detection of the first VCL NAL unit of a primary coded picture	62
7.4.1.2.5	Order of VCL NAL units and association to coded pictures	63
7.4.2	Raw byte sequence payloads and RBSP trailing bits semantics	63
7.4.2.1	Sequence parameter set RBSP semantics	63
7.4.2.1.1	Scaling list semantics	68
7.4.2.1.2	Sequence parameter set extension RBSP semantics	69
7.4.2.2	Picture parameter set RBSP semantics	70
7.4.2.3	Supplemental enhancement information RBSP semantics	73
7.4.2.3.1	Supplemental enhancement information message semantics	73
7.4.2.4	Access unit delimiter RBSP semantics	73
7.4.2.5	End of sequence RBSP semantics	73
7.4.2.6	End of stream RBSP semantics	73
7.4.2.7	Filler data RBSP semantics	73
7.4.2.8	Slice layer without partitioning RBSP semantics	73
7.4.2.9	Slice data partition RBSP semantics	74
7.4.2.9.1	Slice data partition A RBSP semantics	74
7.4.2.9.2	Slice data partition B RBSP semantics	74
7.4.2.9.3	Slice data partition C RBSP semantics	74
7.4.2.10	RBSP slice trailing bits semantics	74
7.4.2.11	RBSP trailing bits semantics	75
7.4.3	Slice header semantics	75
7.4.3.1	Reference picture list reordering semantics	80
7.4.3.2	Prediction weight table semantics	81
7.4.3.3	Decoded reference picture marking semantics	82
7.4.4	Slice data semantics	85
7.4.5	Macroblock layer semantics	85
7.4.5.1	Macroblock prediction semantics	92
7.4.5.2	Sub-macroblock prediction semantics	93
7.4.5.3	Residual data semantics	95

7.4.5.3.1	Residual block CAVLC semantics.....	96
7.4.5.3.2	Residual block CABAC semantics	96
8	Decoding process.....	96
8.1	<i>NAL unit decoding process.....</i>	97
8.2	<i>Slice decoding process.....</i>	98
8.2.1	Decoding process for picture order count	98
8.2.1.1	Decoding process for picture order count type 0	99
8.2.1.2	Decoding process for picture order count type 1	100
8.2.1.3	Decoding process for picture order count type 2	101
8.2.2	Decoding process for macroblock to slice group map	102
8.2.2.1	Specification for interleaved slice group map type.....	103
8.2.2.2	Specification for dispersed slice group map type.....	103
8.2.2.3	Specification for foreground with left-over slice group map type	104
8.2.2.4	Specification for box-out slice group map types.....	104
8.2.2.5	Specification for raster scan slice group map types	105
8.2.2.6	Specification for wipe slice group map types	105
8.2.2.7	Specification for explicit slice group map type.....	105
8.2.2.8	Specification for conversion of map unit to slice group map to macroblock to slice group map	105
8.2.3	Decoding process for slice data partitioning.....	105
8.2.4	Decoding process for reference picture lists construction.....	106
8.2.4.1	Decoding process for picture numbers.....	107
8.2.4.2	Initialisation process for reference picture lists.....	107
8.2.4.2.1	Initialisation process for the reference picture list for P and SP slices in frames.....	108
8.2.4.2.2	Initialisation process for the reference picture list for P and SP slices in fields.....	108
8.2.4.2.3	Initialisation process for reference picture lists for B slices in frames.....	109
8.2.4.2.4	Initialisation process for reference picture lists for B slices in fields.....	109
8.2.4.2.5	Initialisation process for reference picture lists in fields.....	110
8.2.4.3	Reordering process for reference picture lists.....	110
8.2.4.3.1	Reordering process of reference picture lists for short-term reference pictures.....	111
8.2.4.3.2	Reordering process of reference picture lists for long-term reference pictures.....	112
8.2.5	Decoded reference picture marking process	112
8.2.5.1	Sequence of operations for decoded reference picture marking process.....	113
8.2.5.2	Decoding process for gaps in frame_num.....	113
8.2.5.3	Sliding window decoded reference picture marking process.....	114
8.2.5.4	Adaptive memory control decoded reference picture marking process	114
8.2.5.4.1	Marking process of a short-term reference picture as “unused for reference”	114
8.2.5.4.2	Marking process of a long-term reference picture as “unused for reference”	115
8.2.5.4.3	Assignment process of a LongTermFrameIdx to a short-term reference picture	115
8.2.5.4.4	Decoding process for MaxLongTermFrameIdx.....	115
8.2.5.4.5	Marking process of all reference pictures as “unused for reference” and setting MaxLongTermFrameIdx to “no long-term frame indices”.....	115
8.2.5.4.6	Process for assigning a long-term frame index to the current picture	116
8.3	<i>Intra prediction process.....</i>	116
8.3.1	<i>Intra_4x4 prediction process for luma samples</i>	117
8.3.1.1	Derivation process for the Intra4x4PredMode.....	117
8.3.1.2	Intra_4x4 sample prediction	119
8.3.1.2.1	Specification of Intra_4x4_Vertical prediction mode	119
8.3.1.2.2	Specification of Intra_4x4_Horizontal prediction mode	119
8.3.1.2.3	Specification of Intra_4x4_DC prediction mode	120
8.3.1.2.4	Specification of Intra_4x4_Diagonal_Down_Left prediction mode	120
8.3.1.2.5	Specification of Intra_4x4_Diagonal_Down_Right prediction mode	120
8.3.1.2.6	Specification of Intra_4x4_Vertical_Right prediction mode	121
8.3.1.2.7	Specification of Intra_4x4_Horizontal_Down prediction mode	121
8.3.1.2.8	Specification of Intra_4x4_Vertical_Left prediction mode.....	122
8.3.1.2.9	Specification of Intra_4x4_Horizontal_Up prediction mode	122
8.3.2	<i>Intra_8x8 prediction process for luma samples</i>	122
8.3.2.1	Derivation process for Intra8x8PredMode.....	123
8.3.2.2	Intra_8x8 sample prediction	124
8.3.2.2.1	Reference sample filtering process for Intra_8x8 sample prediction	125
8.3.2.2.2	Specification of Intra_8x8_Vertical prediction mode	126
8.3.2.2.3	Specification of Intra_8x8_Horizontal prediction mode	126
8.3.2.2.4	Specification of Intra_8x8_DC prediction mode	127
8.3.2.2.5	Specification of Intra_8x8_Diagonal_Down_Left prediction mode.....	127

8.3.2.2.6	Specification of Intra_8x8_Diagonal_Down_Right prediction mode	127
8.3.2.2.7	Specification of Intra_8x8_Vertical_Right prediction mode	128
8.3.2.2.8	Specification of Intra_8x8_Horizontal_Down prediction mode	128
8.3.2.2.9	Specification of Intra_8x8_Vertical_Left prediction mode	129
8.3.2.2.10	Specification of Intra_8x8_Horizontal_Up prediction mode	129
8.3.3	Intra_16x16 prediction process for luma samples	129
8.3.3.1	Specification of Intra_16x16_Vertical prediction mode	130
8.3.3.2	Specification of Intra_16x16_Horizontal prediction mode	130
8.3.3.3	Specification of Intra_16x16_DC prediction mode	130
8.3.3.4	Specification of Intra_16x16_Plane prediction mode	131
8.3.4	Intra prediction process for chroma samples	131
8.3.4.1	Specification of Intra_Chroma_DC prediction mode	132
8.3.4.2	Specification of Intra_Chroma_Horizontal prediction mode	134
8.3.4.3	Specification of Intra_Chroma_Vertical prediction mode	134
8.3.4.4	Specification of Intra_Chroma_Plane prediction mode	134
8.3.5	Sample construction process for I_PCM macroblocks	134
8.4	<i>Inter prediction process</i>	135
8.4.1	Derivation process for motion vector components and reference indices	137
8.4.1.1	Derivation process for luma motion vectors for skipped macroblocks in P and SP slices	138
8.4.1.2	Derivation process for luma motion vectors for B_Skip, B_Direct_16x16, and B_Direct_8x8	139
8.4.1.2.1	Derivation process for the co-located 4x4 sub-macroblock partitions	139
8.4.1.2.2	Derivation process for spatial direct luma motion vector and reference index prediction mode	142
8.4.1.2.3	Derivation process for temporal direct luma motion vector and reference index prediction mode	144
8.4.1.3	Derivation process for luma motion vector prediction	146
8.4.1.3.1	Derivation process for median luma motion vector prediction	147
8.4.1.3.2	Derivation process for motion data of neighbouring partitions	148
8.4.1.4	Derivation process for chroma motion vectors	149
8.4.2	Decoding process for Inter prediction samples	149
8.4.2.1	Reference picture selection process	150
8.4.2.2	Fractional sample interpolation process	151
8.4.2.2.1	Luma sample interpolation process	152
8.4.2.2.2	Chroma sample interpolation process	155
8.4.2.3	Weighted sample prediction process	156
8.4.2.3.1	Default weighted sample prediction process	156
8.4.2.3.2	Weighted sample prediction process	157
8.5	<i>Transform coefficient decoding process and picture construction process prior to deblocking filter process</i>	159
8.5.1	Specification of transform decoding process for 4x4 luma residual blocks	160
8.5.2	Specification of transform decoding process for luma samples of Intra_16x16 macroblock prediction mode	160
8.5.3	Specification of transform decoding process for 8x8 luma residual blocks	161
8.5.4	Specification of transform decoding process for chroma samples	162
8.5.5	Inverse scanning process for transform coefficients	164
8.5.6	Inverse scanning process for 8x8 luma transform coefficients	164
8.5.7	Derivation process for the chroma quantisation parameters and scaling function	166
8.5.8	Scaling and transformation process for luma DC transform coefficients for Intra_16x16 macroblock type168	166
8.5.9	Scaling and transformation process for chroma DC transform coefficients	169
8.5.10	Scaling and transformation process for residual 4x4 blocks	171
8.5.11	Scaling and transformation process for residual 8x8 luma blocks	173
8.5.12	Picture construction process prior to deblocking filter process	176
8.5.13	Residual colour transform process	177
8.6	<i>Decoding process for P macroblocks in SP slices or SI macroblocks</i>	178
8.6.1	SP decoding process for non-switching pictures	178
8.6.1.1	Luma transform coefficient decoding process	178
8.6.1.2	Chroma transform coefficient decoding process	179
8.6.2	SP and SI slice decoding process for switching pictures	181
8.6.2.1	Luma transform coefficient decoding process	181
8.6.2.2	Chroma transform coefficient decoding process	181
8.7	<i>Deblocking filter process</i>	182
8.7.1	Filtering process for block edges	186
8.7.2	Filtering process for a set of samples across a horizontal or vertical block edge	188
8.7.2.1	Derivation process for the luma content dependent boundary filtering strength	188
8.7.2.2	Derivation process for the thresholds for each block edge	190
8.7.2.3	Filtering process for edges with bS less than 4	191

8.7.2.4	Filtering process for edges for bS equal to 4.....	193
9	Parsing process.....	194
9.1	<i>Parsing process for Exp-Golomb codes.....</i>	<i>194</i>
9.1.1	Mapping process for signed Exp-Golomb codes	195
9.1.2	Mapping process for coded block pattern.....	196
9.2	<i>CAVLC parsing process for transform coefficient levels.....</i>	<i>198</i>
9.2.1	Parsing process for total number of transform coefficient levels and trailing ones	199
9.2.2	Parsing process for level information	201
9.2.2.1	Parsing process for level_prefix.....	202
9.2.3	Parsing process for run information.....	203
9.2.4	Combining level and run information.....	206
9.3	<i>CABAC parsing process for slice data</i>	<i>206</i>
9.3.1	Initialisation process	207
9.3.1.1	Initialisation process for context variables.....	208
9.3.1.2	Initialisation process for the arithmetic decoding engine.....	218
9.3.2	Binarization process.....	219
9.3.2.1	Unary (U) binarization process.....	221
9.3.2.2	Truncated unary (TU) binarization process	221
9.3.2.3	Concatenated unary/ k-th order Exp-Golomb (UEGk) binarization process	222
9.3.2.4	Fixed-length (FL) binarization process.....	222
9.3.2.5	Binarization process for macroblock type and sub-macroblock type	222
9.3.2.6	Binarization process for coded block pattern.....	225
9.3.2.7	Binarization process for mb_qp_delta	225
9.3.3	Decoding process flow.....	225
9.3.3.1	Derivation process for ctxIdx.....	226
9.3.3.1.1	Assignment process of ctxIdxInc using neighbouring syntax elements.....	228
9.3.3.1.1.1	Derivation process of ctxIdxInc for the syntax element mb_skip_flag.....	228
9.3.3.1.1.2	Derivation process of ctxIdxInc for the syntax element mb_field_decoding_flag.....	228
9.3.3.1.1.3	Derivation process of ctxIdxInc for the syntax element mb_type.....	229
9.3.3.1.1.4	Derivation process of ctxIdxInc for the syntax element coded_block_pattern.....	229
9.3.3.1.1.5	Derivation process of ctxIdxInc for the syntax element mb_qp_delta	230
9.3.3.1.1.6	Derivation process of ctxIdxInc for the syntax elements ref_idx_l0 and ref_idx_l1.....	230
9.3.3.1.1.7	Derivation process of ctxIdxInc for the syntax elements mvd_l0 and mvd_l1	231
9.3.3.1.1.8	Derivation process of ctxIdxInc for the syntax element intra_chroma_pred_mode.....	232
9.3.3.1.1.9	Derivation process of ctxIdxInc for the syntax element coded_block_flag	233
9.3.3.1.1.10	Derivation process of ctxIdxInc for the syntax element transform_size_8x8_flag.....	234
9.3.3.1.2	Assignment process of ctxIdxInc using prior decoded bin values	234
9.3.3.1.3	Assignment process of ctxIdxInc for syntax elements significant_coeff_flag, last_significant_coeff_flag, and coeff_abs_level_minus1	235
9.3.3.2	Arithmetic decoding process.....	237
9.3.3.2.1	Arithmetic decoding process for a binary decision	238
9.3.3.2.1.1	State transition process.....	239
9.3.3.2.2	Renormalization process in the arithmetic decoding engine.....	241
9.3.3.2.3	Bypass decoding process for binary decisions	242
9.3.3.2.4	Decoding process for binary decisions before termination	242
9.3.4	Arithmetic encoding process (informative)	243
9.3.4.1	Initialisation process for the arithmetic encoding engine (informative)	243
9.3.4.2	Encoding process for a binary decision (informative)	243
9.3.4.3	Renormalization process in the arithmetic encoding engine (informative).....	244
9.3.4.4	Bypass encoding process for binary decisions (informative).....	246
9.3.4.5	Encoding process for a binary decision before termination (informative).....	246
9.3.4.6	Byte stuffing process (informative)	247
Annex A	Profiles and levels.....	249
A.1	<i>Requirements on video decoder capability</i>	<i>249</i>
A.2	<i>Profiles.....</i>	<i>249</i>
A.2.1	Baseline profile	249
A.2.2	Main profile	250
A.2.3	Extended profile.....	250
A.2.4	High profile.....	250
A.2.5	High 10 profile.....	251
A.2.6	High 4:2:2 profile.....	251
A.2.7	High 4:4:4 profile.....	252

A.3	<i>Levels</i>	252
A.3.1	Level limits common to the Baseline, Main, and Extended profiles.....	252
A.3.2	Level limits common to the High, High 10, High 4:2:2, and High 4:4:4 profiles.....	254
A.3.3	Profile-specific level limits.....	255
A.3.3.1	Baseline profile limits.....	256
A.3.3.2	Main, High, High 10, High 4:2:2, or High 4:4:4 profile limits.....	257
A.3.3.3	Extended Profile Limits.....	258
A.3.4	Effect of level limits on frame rate (informative).....	259
Annex B	Byte stream format	262
B.1	<i>Byte stream NAL unit syntax and semantics</i>	262
B.1.1	Byte stream NAL unit syntax.....	262
B.1.2	Byte stream NAL unit semantics.....	262
B.2	<i>Byte stream NAL unit decoding process</i>	262
B.3	<i>Decoder byte-alignment recovery (informative)</i>	263
Annex C	Hypothetical reference decoder	264
C.1	<i>Operation of coded picture buffer (CPB)</i>	266
C.1.1	Timing of bitstream arrival.....	266
C.1.2	Timing of coded picture removal.....	267
C.2	<i>Operation of the decoded picture buffer (DPB)</i>	268
C.2.1	Decoding of gaps in frame_num and storage of "non-existing" frames.....	268
C.2.2	Picture decoding and output.....	268
C.2.3	Removal of pictures from the DPB before possible insertion of the current picture.....	268
C.2.4	Current decoded picture marking and storage.....	269
C.2.4.1	Marking and storage of a reference decoded picture into the DPB.....	269
C.2.4.2	Storage of a non-reference picture into the DPB.....	269
C.3	<i>Bitstream conformance</i>	269
C.4	<i>Decoder conformance</i>	271
C.4.1	Operation of the output order DPB.....	272
C.4.2	Decoding of gaps in frame_num and storage of "non-existing" pictures.....	272
C.4.3	Picture decoding.....	272
C.4.4	Removal of pictures from the DPB before possible insertion of the current picture.....	272
C.4.5	Current decoded picture marking and storage.....	272
C.4.5.1	Storage and marking of a reference decoded picture into the DPB.....	272
C.4.5.2	Storage and marking of a non-reference decoded picture into the DPB.....	273
C.4.5.3	"Bumping" process.....	273
Annex D	Supplemental enhancement information	275
D.1	<i>SEI payload syntax</i>	276
D.1.1	Buffering period SEI message syntax.....	277
D.1.2	Picture timing SEI message syntax.....	277
D.1.3	Pan-scan rectangle SEI message syntax.....	278
D.1.4	Filler payload SEI message syntax.....	278
D.1.5	User data registered by ITU-T Recommendation T.35 SEI message syntax.....	279
D.1.6	User data unregistered SEI message syntax.....	279
D.1.7	Recovery point SEI message syntax.....	279
D.1.8	Decoded reference picture marking repetition SEI message syntax.....	279
D.1.9	Spare picture SEI message syntax.....	280
D.1.10	Scene information SEI message syntax.....	280
D.1.11	Sub-sequence information SEI message syntax.....	281
D.1.12	Sub-sequence layer characteristics SEI message syntax.....	281
D.1.13	Sub-sequence characteristics SEI message syntax.....	281
D.1.14	Full-frame freeze SEI message syntax.....	282
D.1.15	Full-frame freeze release SEI message syntax.....	282
D.1.16	Full-frame snapshot SEI message syntax.....	282
D.1.17	Progressive refinement segment start SEI message syntax.....	282
D.1.18	Progressive refinement segment end SEI message syntax.....	282
D.1.19	Motion-constrained slice group set SEI message syntax.....	282
D.1.20	Film grain characteristics SEI message syntax.....	283
D.1.21	Deblocking filter display preference SEI message syntax.....	283
D.1.22	Stereo video information SEI message syntax.....	284
D.1.23	Reserved SEI message syntax.....	284
D.2	<i>SEI payload semantics</i>	284
D.2.1	Buffering period SEI message semantics.....	284

D.2.2	Picture timing SEI message semantics.....	285
D.2.3	Pan-scan rectangle SEI message semantics	288
D.2.4	Filler payload SEI message semantics	290
D.2.5	User data registered by ITU-T Recommendation T.35 SEI message semantics.....	290
D.2.6	User data unregistered SEI message semantics	290
D.2.7	Recovery point SEI message semantics.....	290
D.2.8	Decoded reference picture marking repetition SEI message semantics.....	291
D.2.9	Spare picture SEI message semantics	292
D.2.10	Scene information SEI message semantics.....	293
D.2.11	Sub-sequence information SEI message semantics	295
D.2.12	Sub-sequence layer characteristics SEI message semantics.....	296
D.2.13	Sub-sequence characteristics SEI message semantics	297
D.2.14	Full-frame freeze SEI message semantics.....	299
D.2.15	Full-frame freeze release SEI message semantics.....	299
D.2.16	Full-frame snapshot SEI message semantics	299
D.2.17	Progressive refinement segment start SEI message semantics	299
D.2.18	Progressive refinement segment end SEI message semantics.....	300
D.2.19	Motion-constrained slice group set SEI message semantics	300
D.2.20	Film grain characteristics SEI message semantics.....	301
D.2.21	Deblocking filter display preference SEI message semantics.....	306
D.2.22	Stereo video information SEI message semantics	308
D.2.23	Reserved SEI message semantics	309
Annex E	Video usability information.....	310
E.1	<i>VUI syntax</i>	311
E.1.1	VUI parameters syntax	311
E.1.2	HRD parameters syntax.....	312
E.2	<i>VUI semantics</i>	312
E.2.1	VUI parameters semantics	312
E.2.2	HRD parameters semantics.....	323

LIST OF FIGURES

Figure 6-1	– Nominal vertical and horizontal locations of 4:2:0 luma and chroma samples in a frame.....	19
Figure 6-2	– Nominal vertical and horizontal sampling locations of 4:2:0 samples in top and bottom fields.....	20
Figure 6-3	– Nominal vertical and horizontal locations of 4:2:2 luma and chroma samples in a frame.....	20
Figure 6-4	– Nominal vertical and horizontal sampling locations of 4:2:2 samples top and bottom fields.....	21
Figure 6-5	– Nominal vertical and horizontal locations of 4:4:4 luma and chroma samples in a frame.....	21
Figure 6-6	– Nominal vertical and horizontal sampling locations of 4:4:4 samples top and bottom fields.....	22
Figure 6-7	– A picture with 11 by 9 macroblocks that is partitioned into two slices.....	23
Figure 6-8	– Partitioning of the decoded frame into macroblock pairs	23
Figure 6-9	– Macroblock partitions, sub-macroblock partitions, macroblock partition scans, and sub-macroblock partition scans	25
Figure 6-10	– Scan for 4x4 luma blocks.....	26
Figure 6-11	– Scan for 8x8 luma blocks.....	26
Figure 6-12	– Neighbouring macroblocks for a given macroblock	27
Figure 6-13	– Neighbouring macroblocks for a given macroblock in MBAFF frames.....	28
Figure 6-14	– Determination of the neighbouring macroblock, blocks, and partitions (informative)	29
Figure 7-1	– Structure of an access unit not containing any NAL units with nal_unit_type equal to 0, 7, 8, or in the range of 12 to 18, inclusive, or in the range of 20 to 31, inclusive.	62
Figure 8-1	– Intra_4x4 prediction mode directions (informative)	118
Figure 8-2	– Example for temporal direct-mode motion vector inference (informative)	146
Figure 8-3	– Directional segmentation prediction (informative).....	147

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.....	153
Figure 8-5 – Fractional sample position dependent variables in chroma interpolation and surrounding integer position samples A, B, C, and D.....	155
Figure 8-6 – Assignment of the indices of dcY to luma4x4BlkIdx	161
Figure 8-7 – Assignment of the indices of dcC to chroma4x4BlkIdx: (a) chroma_format_idc equal to 1, (b) chroma_format_idc equal to 2, (c) chroma_format_idc equal to 3	163
Figure 8-8 – 4x4 block scans. (a) Zig-zag scan. (b) Field scan (informative)	164
Figure 8-9 – 8x8 block scans. (a) 8x8 zig-zag scan. (b) 8x8 field scan (informative)	165
Figure 8-10 – Boundaries in a macroblock to be filtered.....	183
Figure 8-11 – Convention for describing samples across a 4x4 block horizontal or vertical boundary	187
Figure 9-1 – Illustration of CABAC parsing process for a syntax element SE (informative)	207
Figure 9-2 – Overview of the arithmetic decoding process for a single bin (informative)	238
Figure 9-3 – Flowchart for decoding a decision	239
Figure 9-4 – Flowchart of renormalization	241
Figure 9-5 – Flowchart of bypass decoding process.....	242
Figure 9-6 – Flowchart of decoding a decision before termination	243
Figure 9-7 – Flowchart for encoding a decision	244
Figure 9-8 – Flowchart of renormalization in the encoder	245
Figure 9-9 – Flowchart of PutBit(B).....	245
Figure 9-10 – Flowchart of encoding bypass.....	246
Figure 9-11 – Flowchart of encoding a decision before termination	247
Figure 9-12 – Flowchart of flushing at termination.....	247
Figure C-1 – Structure of byte streams and NAL unit streams for HRD conformance checks	264
Figure C-2 – HRD buffer model.....	265
Figure E-1 – Location of chroma samples for top and bottom fields as a function of chroma_sample_loc_type_top_field and chroma_sample_loc_type_bottom_field	320

LIST OF TABLES

Table 6-1 –SubWidthC, and SubHeightC values derived from chroma_format_idc.....	18
Table 6-2 – Specification of input and output assignments for subclauses 6.4.8.1 to 6.4.8.5.....	29
Table 6-3 – Specification of mbAddrN	33
Table 6-4 - Specification of mbAddrN and yM.....	35
Table 7-1 – NAL unit type codes.....	57
Table 7-2 – Assignment of mnemonic names to scaling list indices and specification of fall-back rule.....	65
Table 7-3 – Specification of default scaling lists Default_4x4_Intra and Default_4x4_Inter.....	66
Table 7-4 – Specification of default scaling lists Default_8x8_Intra and Default_8x8_Inter.....	66
Table 7-5 – Meaning of primary_pic_type	73
Table 7-6 – Name association to slice_type	75
Table 7-7 – reordering_of_pic_nums_idc operations for reordering of reference picture lists.....	81
Table 7-8 – Interpretation of adaptive_ref_pic_marking_mode_flag.....	83

Table 7-9 – Memory management control operation (memory_management_control_operation) values	84
Table 7-10 – Allowed collective macroblock types for slice_type	86
Table 7-11 – Macroblock types for I slices	87
Table 7-12 – Macroblock type with value 0 for SI slices	88
Table 7-13 – Macroblock type values 0 to 4 for P and SP slices	89
Table 7-14 – Macroblock type values 0 to 22 for B slices	90
Table 7-15 – Specification of CodedBlockPatternChroma values	92
Table 7-16 – Relationship between intra_chroma_pred_mode and spatial prediction modes	92
Table 7-17 – Sub-macroblock types in P macroblocks	93
Table 7-18 – Sub-macroblock types in B macroblocks	94
Table 8-1 – Refined slice group map type	102
Table 8-2 – Specification of Intra4x4PredMode[luma4x4BlkIdx] and associated names	117
Table 8-3 – Specification of Intra8x8PredMode[luma8x8BlkIdx] and associated names	123
Table 8-4 – Specification of Intra16x16PredMode and associated names	130
Table 8-5 – Specification of Intra chroma prediction modes and associated names	132
Table 8-6 – Specification of the variable colPic	140
Table 8-7 – Specification of PicCodingStruct(X)	140
Table 8-8 – Specification of mbAddrCol, yM, and vertMvScale	141
Table 8-9 – Assignment of prediction utilization flags	143
Table 8-10 – Derivation of the vertical component of the chroma vector in field coding mode	149
Table 8-11 – Differential full-sample luma locations	153
Table 8-12 – Assignment of the luma prediction sample predPartLXL[x _L , y _L]	155
Table 8-13 – Specification of mapping of idx to c _{ij} for zig-zag and field scan	164
Table 8-14 – Specification of mapping of idx to c _{ij} for 8x8 zig-zag and 8x8 field scan	166
Table 8-15 – Specification of QP _C as a function of qP ₁	167
Table 8-16 – Derivation of offset dependent threshold variables α' and β' from indexA and indexB	191
Table 8-17 – Value of variable t' _{C0} as a function of indexA and bS	192
Table 9-1 – Bit strings with “prefix” and “suffix” bits and assignment to codeNum ranges (informative)	194
Table 9-2 – Exp-Golomb bit strings and codeNum in explicit form and used as ue(v) (informative)	195
Table 9-3 – Assignment of syntax element to codeNum for signed Exp-Golomb coded syntax elements se(v)	196
Table 9-4 – Assignment of codeNum to values of coded_block_pattern for macroblock prediction modes	196
Table 9-5 – coeff_token mapping to TotalCoeff(coeff_token) and TrailingOnes(coeff_token)	200
Table 9-6 – Codeword table for level_prefix (informative)	203
Table 9-7 – total_zeros tables for 4x4 blocks with TotalCoeff(coeff_token) 1 to 7	204
Table 9-8 – total_zeros tables for 4x4 blocks with TotalCoeff(coeff_token) 8 to 15	205
Table 9-9 – total_zeros tables for chroma DC 2x2 and 2x4 blocks	205
Table 9-10 – Tables for run_before	206
Table 9-11 – Association of ctxIdx and syntax elements for each slice type in the initialisation process	208
Table 9-12 – Values of variables m and n for ctxIdx from 0 to 10	209
Table 9-13 – Values of variables m and n for ctxIdx from 11 to 23	210

Table 9-14 – Values of variables m and n for ctxIdx from 24 to 39.....	210
Table 9-15 – Values of variables m and n for ctxIdx from 40 to 53.....	210
Table 9-16 – Values of variables m and n for ctxIdx from 54 to 59, and 399 to 401	211
Table 9-17 – Values of variables m and n for ctxIdx from 60 to 69.....	211
Table 9-18 – Values of variables m and n for ctxIdx from 70 to 104.....	212
Table 9-19 – Values of variables m and n for ctxIdx from 105 to 165.....	213
Table 9-20 – Values of variables m and n for ctxIdx from 166 to 226.....	214
Table 9-21 – Values of variables m and n for ctxIdx from 227 to 275.....	215
Table 9-22 – Values of variables m and n for ctxIdx from 277 to 337.....	216
Table 9-23 – Values of variables m and n for ctxIdx from 338 to 398.....	217
Table 9-24 – Values of variables m and n for ctxIdx from 402 to 459.....	218
Table 9-25 – Syntax elements and associated types of binarization, maxBinIdxCtx, and ctxIdxOffset.....	220
Table 9-26 – Bin string of the unary binarization (informative).....	221
Table 9-27 – Binarization for macroblock types in I slices.....	223
Table 9-28 – Binarization for macroblock types in P, SP, and B slices.....	224
Table 9-29 – Binarization for sub-macroblock types in P, SP, and B slices.....	225
Table 9-30 – Assignment of ctxIdxInc to binIdx for all ctxIdxOffset values except those related to the syntax elements coded_block_flag, significant_coeff_flag, last_significant_coeff_flag, and coeff_abs_level_minus1.....	227
Table 9-31 – Assignment of ctxIdxBlockCatOffset to ctxBlockCat for syntax elements coded_block_flag, significant_coeff_flag, last_significant_coeff_flag, and coeff_abs_level_minus1	228
Table 9-32 – Specification of ctxIdxInc for specific values of ctxIdxOffset and binIdx.....	235
Table 9-33 – Specification of ctxBlockCat for the different blocks.....	235
Table 9-34 – Mapping of scanning position to ctxIdxInc for ctxBlockCat == 5.....	236
Table 9-35 – Specification of rangeTabLPS depending on pStateIdx and qCodIRangeIdx.....	240
Table 9-36 – State transition table.....	241
Table A-1 – Level limits.....	254
Table A-2 – Specification of cpbBrVclFactor and cpbBrNalFactor.....	256
Table A-3 – Baseline profile level limits.....	257
Table A-4 – Main, High, High 10, High 4:2:2, or High 4:4:4 profile level limits.....	257
Table A-5 – Extended profile level limits.....	258
Table A-6 – Maximum frame rates (frames per second) for some example frame sizes.....	259
Table D-1 – Interpretation of pic_struct.....	286
Table D-2 – Mapping of ct_type to source picture scan.....	287
Table D-3 – Definition of counting_type values.....	287
Table D-4 – scene_transition_type values.....	294
Table D-5 – model_id values.....	301
Table D-6 – blending_mode_id values.....	302
Table E-1 – Meaning of sample aspect ratio indicator.....	313
Table E-2 – Meaning of video_format.....	314
Table E-3 – Colour primaries.....	315

Table E-4 – Transfer characteristics	316
Table E-5 – Matrix coefficients	319
Table E-6 – Divisor for computation of $\Delta_{\tilde{r},\text{dpb}}(n)$	321

Foreword

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardising telecommunications on a world-wide basis. The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups that, in turn, produce Recommendations on these topics. The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1. In some areas of information technology that fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialised system for world-wide standardisation. National Bodies that are members of ISO and IEC participate in the development of International Standards through technical committees established by the respective organisation to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organisations, 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. 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.

This Recommendation | International Standard was prepared jointly by ITU-T SG 16 Q.6, also known as VCEG (Video Coding Experts Group), and by ISO/IEC JTC 1/SC 29/WG 11, also known as MPEG (Moving Picture Experts Group). VCEG was formed in 1997 to maintain prior ITU-T video coding standards and develop new video coding standard(s) appropriate for a wide range of conversational and non-conversational services. MPEG was formed in 1988 to establish standards for coding of moving pictures and associated audio for various applications such as digital storage media, distribution, and communication.

In this Recommendation | International Standard Annexes A through E contain normative requirements and are an integral part of this Recommendation | International Standard.

ITU-T Recommendation H.264

Advanced video coding for generic audiovisual services

0 Introduction

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

0.1 Prologue

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

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 Video Team (JVT) in 2001 for development of a new Recommendation | International Standard.

0.2 Purpose

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

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 communication. It is also designed to enable the use of the coded video representation in a flexible manner for a wide variety of network environments. 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.

0.3 Applications

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

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

CATV	Cable TV on optical networks, copper, etc.
DBS	Direct broadcast satellite video services
DSL	Digital subscriber line video services
DTTB	Digital terrestrial television broadcasting
ISM	Interactive storage media (optical disks, etc.)
MMM	Multimedia mailing
MSPN	Multimedia services over packet networks
RTC	Real-time conversational services (videoconferencing, videophone, etc.)
RVS	Remote video surveillance
SSM	Serial storage media (digital VTR, etc.)

0.4 Publication and versions of this specification

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

This specification has been jointly developed by ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group. It is published as technically-aligned twin text in both organizations ITU-T and ISO/IEC.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 1 refers to the first (2003) approved version of this Recommendation | International Standard.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 2 refers to the integrated text containing the corrections specified in the first technical corrigendum.

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 3 refers to the integrated text containing both the first technical corrigendum (2004) and the first amendment, which is referred to as the "Fidelity range extensions".

ITU-T Rec. H.264 | ISO/IEC 14496-10 version 4 (the current specification) refers to the integrated text containing the first technical corrigendum (2004), the first amendment (the "Fidelity range extensions"), and an additional technical corrigendum (2005). In the ITU-T, the next published version after version 2 was version 4 (due to the completion of the drafting work for version 4 prior to the approval opportunity for a final version 3 text).

0.5 Profiles and levels

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

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" 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 by 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, "levels" are specified within each profile. A level 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).

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.

0.6 Overview of the design characteristics

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

The coded representation specified in the syntax is designed to enable a high compression capability for a desired image quality. With the exception of the transform bypass mode of operation for lossless coding in the High 4:4:4 profile and the I_PCM mode of operation in all profiles, 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 is then further compressed using a transform to remove spatial correlation inside the transform block before it is quantised, producing an 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 are combined with the quantised transform coefficient information and encoded using either variable length codes or arithmetic coding.

0.6.1 Predictive coding

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

Because of the conflicting requirements of random access and highly efficient compression, two main coding types are specified. Intra coding is done without reference to other pictures. Intra coding may provide access points to the coded sequence where decoding can begin and continue correctly, but typically also shows only moderate compression efficiency. Inter coding (predictive or bi-predictive) is more efficient using inter prediction of each block of sample values from some previously decoded picture selected by the encoder. In contrast to some other video coding standards, pictures coded using bi-predictive inter prediction may also be used as references for inter coding of other pictures.

The application of the three coding types to pictures in a sequence is flexible, and the order of the decoding process is generally not the same as the order of the source picture capture process in the encoder or the output order from the decoder for display. The choice is left to the encoder and will depend on the requirements of the application. The decoding order is specified such that the decoding of pictures that use inter-picture prediction follows later in decoding order than other pictures that are referenced in the decoding process.

0.6.2 Coding of progressive and interlaced video

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

This Recommendation | International Standard specifies a syntax and decoding process for video that originated in either progressive-scan or interlaced-scan form, which may be mixed together in the same sequence. The two fields of an interlaced frame are separated in capture time while the two fields of a progressive frame share the same capture time. Each field may be coded separately or the two fields may be coded together as a frame. Progressive frames are typically coded as a frame. For interlaced video, the encoder can choose between frame coding and field coding. Frame coding or field coding can be adaptively selected on a picture-by-picture basis and also on a more localized basis within a coded frame. Frame coding is typically preferred when the video scene contains significant detail with limited motion. Field coding typically works better when there is fast picture-to-picture motion.

0.6.3 Picture partitioning into macroblocks and smaller partitions

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

As in previous video coding Recommendations and International Standards, a macroblock, consisting of a 16x16 block of luma samples and two corresponding blocks of chroma samples, is used as the basic processing unit of the video decoding process.

A macroblock can be further partitioned for inter prediction. The selection of the size of inter prediction partitions is a result of a trade-off between the coding gain provided by using motion compensation with smaller blocks and the quantity of data needed to represent the data for motion compensation. In this Recommendation | International Standard the inter prediction process can form segmentations for motion representation as small as 4x4 luma samples in size, using motion vector accuracy of one-quarter of the luma sample grid spacing displacement. The process for inter prediction of a sample block can also involve the selection of the picture to be used as the reference picture from a number of stored previously-decoded pictures. Motion vectors are encoded differentially with respect to predicted values formed from nearby encoded motion vectors.

Typically, the encoder calculates appropriate motion vectors and other data elements represented in the video data stream. This motion estimation process in the encoder and the selection of whether to use inter prediction for the representation of each region of the video content is not specified in this Recommendation | International Standard.

0.6.4 Spatial redundancy reduction

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

Both source pictures and prediction residuals have high spatial redundancy. This Recommendation | International Standard is based on the use of a block-based transform method for spatial redundancy removal. After inter prediction from previously-decoded samples in other pictures or spatial-based prediction from previously-decoded samples within the current picture, the resulting prediction residual is split into 4x4 blocks. These are converted into the transform domain where they are quantised. After quantisation many of the transform coefficients are zero or have low amplitude and can thus be represented with a small amount of encoded data. The processes of transformation and quantisation in the encoder are not specified in this Recommendation | International Standard.

0.7 How to read this specification

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

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; i.e., 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). 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 seven profiles (Baseline, Main, Extended, High, High 10, High 4:2:2 and High 4:4:4), each being tailored to certain application domains, and defines the so-called 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 and its use to check bitstream and decoder conformance. Annex D specifies syntax and semantics for supplemental enhancement information message payloads. Finally, 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.

1 Scope

This document specifies ITU-T Recommendation H.264 | ISO/IEC International Standard ISO/IEC 14496-10 video coding.

2 Normative references

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

- ITU-T Recommendation T.35 (2000), *Procedure for the allocation of ITU-T defined codes for non-standard facilities*.
- ISO/IEC 11578:1996, Annex A, *Universal Unique Identifier*.
- ISO/CIE 10527:1991, *Colorimetric Observers*.

3 Definitions

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

- 3.1 access unit:** A set of *NAL units* always containing exactly one *primary coded picture*. In addition to the *primary coded picture*, an access unit may also contain one or more *redundant coded pictures* or other *NAL units* not containing *slices* or *slice data partitions* of a *coded picture*. 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 one or both dimensions is non-zero.
- 3.3 adaptive binary arithmetic decoding process:** An entropy *decoding process* that derives the values of *bins* from a *bitstream* produced by an *adaptive binary arithmetic encoding process*.
- 3.4 adaptive binary arithmetic encoding process:** An entropy *encoding process*, not normatively specified in this Recommendation | International Standard, that codes a sequence of *bins* and produces a *bitstream* that can be decoded using the *adaptive binary arithmetic decoding process*.
- 3.5 alpha blending:** A process not specified by this Recommendation | International Standard, in which an *auxiliary coded picture* is used in combination with a *primary coded picture* and with other data not specified by this Recommendation | International Standard in the *display process*. In an alpha blending process, the samples of an *auxiliary coded picture* are interpreted as indications of the degree of opacity (or, equivalently, the degrees of transparency) associated with the corresponding *luma* samples of the *primary coded picture*.

- 3.6 arbitrary slice order:** A *decoding order* of *slices* in which the *macroblock address* of the first *macroblock* of some *slice* of a *picture* may be less than the *macroblock address* of the first *macroblock* of some other preceding *slice* of the same *coded picture*.
- 3.7 auxiliary coded picture:** A *picture* that supplements the *primary coded picture* that may be used in combination with other data not specified by this Recommendation | International Standard in the *display process*. An auxiliary coded picture has the same syntactic and semantic restrictions as a monochrome *redundant coded picture*. An auxiliary coded picture must contain the same number of *macroblocks* as the *primary coded picture*. Auxiliary coded pictures have no normative effect on the *decoding process*. See also *primary coded picture* and *redundant coded picture*.
- 3.8 B slice:** A *slice* that may be decoded using *intra prediction* from decoded samples within the same *slice* or *inter prediction* from previously-decoded *reference pictures*, using at most two *motion vectors* and *reference indices* to *predict* the sample values of each *block*.
- 3.9 bin:** One bit of a *bin string*.
- 3.10 binarization:** A set of *bin strings* for all possible values of a *syntax element*.
- 3.11 binarization process:** A unique mapping process of all possible values of a *syntax element* onto a set of *bin strings*.
- 3.12 bin string:** A string of *bins*. A bin string is an intermediate binary representation of values of *syntax elements* from the *binarization* of the *syntax element*.
- 3.13 bi-predictive slice:** See *B slice*.
- 3.14 bitstream:** A sequence of bits that forms the representation of *coded pictures* and associated data forming one or more *coded video sequences*. Bitstream is a collective term used to refer either to a *NAL unit stream* or a *byte stream*.
- 3.15 block:** An MxN (M-column by N-row) array of samples, or an MxN array of *transform coefficients*.
- 3.16 bottom field:** One of two *fields* that comprise a *frame*. Each row of a *bottom field* is spatially located immediately below a corresponding row of a *top field*.
- 3.17 bottom macroblock (of a macroblock pair):** The *macroblock* within a *macroblock pair* that contains the samples in the bottom row of samples for the *macroblock pair*. For a *field macroblock pair*, the bottom macroblock represents the samples from the region of the *bottom field* of the *frame* that lie within the spatial region of the *macroblock pair*. For a *frame macroblock pair*, the bottom macroblock represents the samples of the *frame* that lie within the bottom half of the spatial region of the *macroblock pair*.
- 3.18 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*.
- 3.19 byte:** A sequence of 8 bits, written and read with the most significant bit on the left and the least significant bit on the right. When represented in a sequence of data bits, the most significant bit of a byte is first.
- 3.20 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*. 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.
- 3.21 byte stream:** An encapsulation of a *NAL unit stream* containing *start code prefixes* and *NAL units* as specified in Annex B.
- 3.22 can:** A term used to refer to behaviour that is allowed, but not necessarily required.
- 3.23 category:** A number associated with each *syntax element*. The category is used to specify the allocation of *syntax elements* to *NAL units* for *slice data partitioning*. It may also be used in a manner determined by the application to refer to classes of *syntax elements* in a manner not specified in this Recommendation | International Standard.
- 3.24 chroma:** An adjective specifying that a sample array or single sample is representing one of the two colour difference signals related to the primary colours. The symbols used for a chroma array or sample are Cb and Cr.
- NOTE – The term chroma is used rather than the term chrominance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term chrominance.
- 3.25 coded field:** A *coded representation* of a *field*.

- 3.26 coded frame:** A coded representation of a frame.
- 3.27 coded picture:** A coded representation of a picture. A coded picture may be either a coded field or a coded frame. Coded picture is a collective term referring to a primary coded picture or a redundant coded picture, but not to both together.
- 3.28 coded picture buffer (CPB):** A first-in first-out buffer containing access units in decoding order specified in the hypothetical reference decoder in Annex C.
- 3.29 coded representation:** A data element as represented in its coded form.
- 3.30 coded video sequence:** A sequence of access units that consists, in decoding order, of an IDR access unit followed by zero or more non-IDR access units including all subsequent access units up to but not including any subsequent IDR access unit.
- 3.31 component:** An array or single sample from one of the three arrays (*luma* and two *chroma*) that make up a field or frame.
- 3.32 complementary field pair:** A collective term for a complementary reference field pair or a complementary non-reference field pair.
- 3.33 complementary non-reference field pair:** Two non-reference fields that are in consecutive access units in decoding order as two coded fields of opposite parity where the first field is not already a paired field.
- 3.34 complementary reference field pair:** Two reference fields that are in consecutive access units in decoding order as two coded fields and share the same value of the frame_num syntax element, where the second field in decoding order is not an IDR picture and does not include a memory_management_control_operation syntax element equal to 5.
- 3.35 context variable:** A variable specified for the adaptive binary arithmetic decoding process of a bin by an equation containing recently decoded bins.
- 3.36 DC transform coefficient:** A transform coefficient for which the frequency index is zero in all dimensions.
- 3.37 decoded picture:** A decoded picture is derived by decoding a coded picture. A decoded picture is either a decoded frame, or a decoded field. A decoded field is either a decoded top field or a decoded bottom field.
- 3.38 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.
- 3.39 decoder:** An embodiment of a decoding process.
- 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 Recommendation | International Standard that reads a bitstream and derives decoded pictures from it.
- 3.42 direct prediction:** An inter prediction for a block for which no motion vector is decoded. Two direct prediction modes are specified that are referred to as spatial direct prediction and temporal prediction mode.
- 3.43 display process:** A process not specified in this Recommendation | International Standard having, as its input, the cropped decoded pictures that are the output of the decoding process.
- 3.44 decoder under test (DUT):** A decoder that is tested for conformance to this Recommendation | International Standard 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 of the output of the two decoders.
- 3.45 emulation prevention byte:** A byte equal to 0x03 that may be present within a NAL unit. The presence of emulation prevention bytes ensures that no sequence of consecutive byte-aligned bytes in the NAL unit contains a start code prefix.
- 3.46 encoder:** An embodiment of an encoding process.
- 3.47 encoding process:** A process, not specified in this Recommendation | International Standard, that produces a bitstream conforming to this Recommendation | International Standard.
- 3.48 field:** An assembly of alternate rows of a frame. A frame is composed of two fields, a top field and a bottom field.
- 3.49 field macroblock:** A macroblock containing samples from a single field. All macroblocks of a coded field are field macroblocks. When macroblock-adaptive frame/field decoding is in use, some macroblocks of a coded frame may be field macroblocks.

- 3.50 field macroblock pair:** A *macroblock pair* decoded as two *field macroblocks*.
- 3.51 field scan:** A specific sequential ordering of *transform coefficients* that differs from the *zig-zag scan* by scanning columns more rapidly than rows. Field scan is used for *transform coefficients* in *field macroblocks*.
- 3.52 flag:** A variable that can take one of the two possible values 0 and 1.
- 3.53 frame:** A *frame* contains an array of *luma* samples and two corresponding arrays of *chroma* samples. A *frame* consists of two *fields*, a *top field* and a *bottom field*.
- 3.54 frame macroblock:** A *macroblock* representing samples from the two *fields* of a *coded frame*. When *macroblock-adaptive frame/field decoding* is not in use, all *macroblocks* of a *coded frame* are *frame macroblocks*. When *macroblock-adaptive frame/field decoding* is in use, some *macroblocks* of a *coded frame* may be *frame macroblocks*.
- 3.55 frame macroblock pair:** A *macroblock pair* decoded as two *frame macroblocks*.
- 3.56 frequency index:** A one-dimensional or two-dimensional index associated with a *transform coefficient* prior to an *inverse transform* part of the *decoding process*.
- 3.57 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.
- 3.58 hypothetical stream scheduler (HSS):** A hypothetical delivery mechanism for the timing and data flow of the input of a *bitstream* into the *hypothetical reference decoder*. The HSS is used for checking the conformance of a *bitstream* or a *decoder*.
- 3.59 I slice:** A *slice* that is not an *SI slice* that is decoded using *prediction* only from decoded samples within the same *slice*.
- 3.60 informative:** A term used to refer to content provided in this Recommendation | International Standard that is not an integral part of this Recommendation | International Standard. Informative content does not establish any mandatory requirements for conformance to this Recommendation | International Standard.
- 3.61 instantaneous decoding refresh (IDR) access unit:** An *access unit* in which the *primary coded picture* is an *IDR picture*.
- 3.62 instantaneous decoding refresh (IDR) picture:** A *coded picture* in which all *slices* are *I* or *SI slices* that causes the *decoding process* to mark all *reference pictures* as "unused for reference" immediately after decoding the *IDR picture*. After the decoding of an *IDR picture* all following *coded pictures* in *decoding order* can be decoded without *inter prediction* from any *picture* decoded prior to the *IDR picture*. The first *picture* of each *coded video sequence* is an *IDR picture*.
- 3.63 inter coding:** Coding of a *block*, *macroblock*, *slice*, or *picture* that uses *inter prediction*.
- 3.64 inter prediction:** A *prediction* derived from decoded samples of *reference pictures* other than the current decoded *picture*.
- 3.65 interpretation sample value:** A possibly-altered value corresponding to a decoded sample value of an *auxiliary coded picture* that may be generated for use in the *display process*. Interpretation sample values are not used in the *decoding process* and have no normative effect on the *decoding process*.
- 3.66 intra coding:** Coding of a *block*, *macroblock*, *slice*, or *picture* that uses *intra prediction*.
- 3.67 intra prediction:** A *prediction* derived from the decoded samples of the same decoded *slice*.
- 3.68 intra slice:** See *I slice*.
- 3.69 inverse transform:** A part of the *decoding process* by which a set of *transform coefficients* are converted into spatial-domain values, or by which a set of *transform coefficients* are converted into *DC transform coefficients*.
- 3.70 layer:** One of a set of syntactical structures in a non-branching hierarchical relationship. Higher layers contain lower layers. The coding layers are the *coded video sequence*, *picture*, *slice*, and *macroblock* layers.
- 3.71 level:** A defined set of constraints on the values that may be taken by the *syntax elements* and variables of this Recommendation | International Standard. 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 specified constraints, support a different level for each supported *profile*. In a different context, level is the value of a *transform coefficient* prior to *scaling*.

- 3.72 list 0 (list 1) motion vector:** A *motion vector* associated with a *reference index* pointing into *reference picture list 0 (list 1)*.
- 3.73 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)*.
- 3.74 luma:** An adjective specifying that a sample array or single sample is representing the monochrome signal related to the primary colours. The symbol or subscript used for luma is Y or L.
NOTE – The term luma is used rather than the term luminance in order to avoid the implication of the use of linear light transfer characteristics that is often associated with the term luminance. The symbol L is sometimes used instead of the symbol Y to avoid confusion with the symbol y as used for vertical location.
- 3.75 macroblock:** A 16x16 *block* of *luma* samples and two corresponding *blocks* of *chroma* samples. The division of a *slice* or a *macroblock pair* into macroblocks is a *partitioning*.
- 3.76 macroblock-adaptive frame/field decoding:** A *decoding process* for *coded frames* in which some *macroblocks* may be decoded as *frame macroblocks* and others may be decoded as *field macroblocks*.
- 3.77 macroblock address:** When *macroblock-adaptive frame/field decoding* is not in use, a macroblock address is the index of a macroblock in a *macroblock raster scan* of the *picture* starting with zero for the top-left *macroblock* in a *picture*. When *macroblock-adaptive frame/field decoding* is in use, the macroblock address of the *top macroblock* of a *macroblock pair* is two times the index of the *macroblock pair* in a *macroblock pair raster scan* of the *picture*, and the macroblock address of the *bottom macroblock* of a *macroblock pair* is the macroblock address of the corresponding *top macroblock* plus 1. The macroblock address of the *top macroblock* of each *macroblock pair* is an even number and the macroblock address of the *bottom macroblock* of each *macroblock pair* is an odd number.
- 3.78 macroblock location:** The two-dimensional coordinates of a *macroblock* in a *picture* denoted by (x, y). For the top left *macroblock* of the *picture* (x, y) is equal to (0, 0). x is incremented by 1 for each *macroblock* column from left to right. When *macroblock-adaptive frame/field decoding* is not in use, y is incremented by 1 for each *macroblock* row from top to bottom. When *macroblock-adaptive frame/field decoding* is in use, y is incremented by 2 for each *macroblock pair* row from top to bottom, and is incremented by an additional 1 when a macroblock is a *bottom macroblock*.
- 3.79 macroblock pair:** A pair of vertically contiguous *macroblocks* in a *frame* that is coupled for use in *macroblock-adaptive frame/field decoding*. The division of a *slice* into macroblock pairs is a *partitioning*.
- 3.80 macroblock partition:** A *block* of *luma* samples and two corresponding *blocks* of *chroma* samples resulting from a *partitioning* of a *macroblock* for *inter prediction*.
- 3.81 macroblock to slice group map:** A means of mapping *macroblocks* of a *picture* into *slice groups*. The macroblock to slice group map consists of a list of numbers, one for each coded *macroblock*, specifying the *slice group* to which each coded *macroblock* belongs.
- 3.82 map unit to slice group map:** A means of mapping *slice group map units* of a *picture* into *slice groups*. The map unit to slice group map consists of a list of numbers, one for each *slice group map unit*, specifying the *slice group* to which each coded *slice group map unit* belongs.
- 3.83 may:** A term used to refer to behaviour that is allowed, but not necessarily required. 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.
- 3.84 memory management control operation:** Seven operations that control *reference picture marking*.
- 3.85 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*.
- 3.86 must:** A term used in expressing an observation about a requirement or an implication of a requirement that is specified elsewhere in this Recommendation | International Standard. This term is used exclusively in an *informative* context.
- 3.87 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*.
- 3.88 NAL unit stream:** A sequence of *NAL units*.
- 3.89 non-paired field:** A collective term for a *non-paired reference field* or a *non-paired non-reference field*.
- 3.90 non-paired non-reference field:** A decoded *non-reference field* that is not part of a *complementary non-reference field pair*.

- 3.91 **non-paired reference field**: A decoded *reference field* that is not part of a *complementary reference field pair*.
- 3.92 **non-reference field**: A *field* coded with *nal_ref_idc* equal to 0.
- 3.93 **non-reference frame**: A *frame* coded with *nal_ref_idc* equal to 0.
- 3.94 **non-reference picture**: A *picture* coded with *nal_ref_idc* equal to 0. A *non-reference picture* is not used for *inter prediction* of any other *pictures*.
- 3.95 **note**: A term used to prefix *informative* remarks. This term is used exclusively in an *informative* context.
- 3.96 **opposite parity**: The *opposite parity* of *top* is *bottom*, and vice versa.
- 3.97 **output order**: The order in which the *decoded pictures* are output from the *decoded picture buffer*.
- 3.98 **P slice**: A *slice* that may be decoded using *intra prediction* from decoded samples within the same *slice* or *inter prediction* from previously-decoded *reference pictures*, using at most one *motion vector* and *reference index* to *predict* the sample values of each *block*.
- 3.99 **parameter**: A *syntax element* of a *sequence parameter set* or a *picture parameter set*. Parameter is also used as part of the defined term *quantisation parameter*.
- 3.100 **parity**: The parity of a *field* can be *top* or *bottom*.
- 3.101 **partitioning**: The division of a set into subsets such that each element of the set is in exactly one of the subsets.
- 3.102 **picture**: A collective term for a *field* or a *frame*.
- 3.103 **picture parameter set**: A *syntax structure* containing *syntax elements* that apply to zero or more entire *coded pictures* as determined by the *pic_parameter_set_id syntax element* found in each *slice header*.
- 3.104 **picture order count**: A variable having a value that is non-decreasing with increasing *picture* position in output order relative to the previous *IDR picture* in *decoding order* or relative to the previous *picture* containing the *memory management control operation* that marks all *reference pictures* as “unused for reference”.
- 3.105 **prediction**: An embodiment of the *prediction process*.
- 3.106 **prediction process**: The use of a *predictor* to provide an estimate of the sample value or data element currently being decoded.
- 3.107 **predictive slice**: See *P slice*.
- 3.108 **predictor**: A combination of specified values or previously decoded sample values or data elements used in the *decoding process* of subsequent sample values or data elements.
- 3.109 **primary coded picture**: The coded representation of a *picture* to be used by the *decoding process* for a bitstream conforming to this Recommendation | International Standard. The primary coded picture contains all *macroblocks* of the *picture*. The only *pictures* that have a normative effect on the *decoding process* are primary coded pictures. See also *redundant coded picture*.
- 3.110 **profile**: A specified subset of the syntax of this Recommendation | International Standard.
- 3.111 **quantisation parameter**: A variable used by the *decoding process* for *scaling* of *transform coefficient levels*.
- 3.112 **random access**: The act of starting the decoding process for a *bitstream* at a point other than the beginning of the stream.
- 3.113 **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.
- 3.114 **raw byte sequence payload (RBSP)**: A syntax structure containing an integer number of *bytes* that is encapsulated in a *NAL unit*. An RBSP is either empty or has the form of a *string of data bits* containing *syntax elements* followed by an *RBSP stop bit* and followed by zero or more subsequent bits equal to 0.
- 3.115 **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*. The location of the end of the *string of data bits* 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.

- 3.116 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*.
- 3.117 redundant coded picture:** A coded representation of a *picture* or a part of a *picture*. The content of a redundant coded picture shall not be used by the *decoding process* for a *bitstream* conforming to this Recommendation | International Standard. A *redundant coded picture* is not required to contain all *macroblocks* in the *primary coded picture*. Redundant coded pictures have no normative effect on the *decoding process*. See also *primary coded picture*.
- 3.118 reference field:** A *reference field* may be used for *inter prediction* when *P*, *SP*, and *B slices* of a *coded field* or *field macroblocks* of a *coded frame* are decoded. See also *reference picture*.
- 3.119 reference frame:** A *reference frame* may be used for *inter prediction* when *P*, *SP*, and *B slices* of a *coded frame* are decoded. See also *reference picture*.
- 3.120 reference index:** An index into a *reference picture list*.
- 3.121 reference picture:** A *picture* with *nal_ref_idc* not equal to 0. A *reference picture* contains samples that may be used for *inter prediction* in the *decoding process* of subsequent *pictures* in *decoding order*.
- 3.122 reference picture list:** A list of *reference pictures* that is used for *inter prediction* of a *P*, *B*, or *SP slice*. For the *decoding process* of a *P* or *SP slice*, there is one reference picture list. For the *decoding process* of a *B slice*, there are two reference picture lists.
- 3.123 reference picture list 0:** A *reference picture list* used for *inter prediction* of a *P*, *B*, or *SP slice*. All *inter prediction* used for *P* and *SP slices* uses reference picture list 0. Reference picture list 0 is one of two *reference picture lists* used for *inter prediction* for a *B slice*, with the other being *reference picture list 1*.
- 3.124 reference picture list 1:** A *reference picture list* used for *inter prediction* of a *B slice*. Reference picture list 1 is one of two lists of *reference picture lists* used for *inter prediction* for a *B slice*, with the other being *reference picture list 0*.
- 3.125 reference picture marking:** Specifies, in the *bitstream*, how the *decoded pictures* are marked for *inter prediction*.
- 3.126 reserved:** The term reserved, when used in the clauses specifying some values of a particular *syntax element*, are for future use by ITU-T | ISO/IEC. These values shall not be used in *bitstreams* conforming to this Recommendation | International Standard, but may be used in future extensions of this Recommendation | International Standard by ITU-T | ISO/IEC.
- 3.127 residual:** The decoded difference between a *prediction* of a sample or data element and its decoded value.
- 3.128 run:** A number of consecutive data elements represented in the *decoding process*. In one context, the number of zero-valued *transform coefficient levels* preceding a non-zero *transform coefficient level* in the list of *transform coefficient levels* generated by a *zig-zag scan* or a *field scan*. In other contexts, run refers to a number of *macroblocks*.
- 3.129 sample aspect ratio:** Specifies, for assisting the display process, which is not specified in this Recommendation | International Standard, 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 *frame*. Sample aspect ratio is expressed as $h:v$, where h is horizontal width and v is vertical height (in arbitrary units of spatial distance).
- 3.130 scaling:** The process of multiplying *transform coefficient levels* by a factor, resulting in *transform coefficients*.
- 3.131 sequence parameter set:** A *syntax structure* containing *syntax elements* that apply to zero or more entire *coded video sequences* as determined by the content of a *seq_parameter_set_id syntax element* found in the *picture parameter set* referred to by the *pic_parameter_set_id syntax element* found in each *slice header*.
- 3.132 shall:** A term used to express mandatory requirements for conformance to this Recommendation | International Standard. 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 results to the *decoding process* described herein conforms to the *decoding process* requirements of this Recommendation | International Standard.
- 3.133 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 Recommendation | International Standard.

- 3.134 **SI slice:** A *slice* that is coded using *prediction* only from decoded samples within the same *slice* and using quantisation of the *prediction* samples. An SI slice can be coded such that its decoded samples can be constructed identically to an *SP slice*.
- 3.135 **skipped macroblock:** A *macroblock* for which no data is coded other than an indication that the *macroblock* is to be decoded as "skipped". This indication may be common to several *macroblocks*.
- 3.136 **slice:** An integer number of *macroblocks* or *macroblock pairs* ordered consecutively in the *raster scan* within a particular *slice group*. For the *primary coded picture*, the division of each *slice group* into slices is a *partitioning*. Although a slice contains *macroblocks* or *macroblock pairs* that are consecutive in the *raster scan* within a *slice group*, these *macroblocks* or *macroblock pairs* are not necessarily consecutive in the *raster scan* within the *picture*. The addresses of the *macroblocks* are derived from the address of the first *macroblock* in a slice (as represented in the *slice header*) and the *macroblock to slice group map*.
- 3.137 **slice data partitioning:** A method of *partitioning* selected *syntax elements* into *syntax structures* based on a *category* associated with each *syntax element*.
- 3.138 **slice group:** A subset of the *macroblocks* or *macroblock pairs* of a *picture*. The division of the *picture* into slice groups is a *partitioning* of the *picture*. The partitioning is specified by the *macroblock to slice group map*.
- 3.139 **slice group map units:** The units of the *map unit to slice group map*.
- 3.140 **slice header:** A part of a coded *slice* containing the data elements pertaining to the first or all *macroblocks* represented in the *slice*.
- 3.141 **source:** Term used to describe the video material or some of its attributes before encoding.
- 3.142 **SP slice:** A *slice* that is coded using *inter prediction* from previously-decoded *reference pictures*, using at most one *motion vector* and *reference index* to *predict* the sample values of each *block*. An SP slice can be coded such that its decoded samples can be constructed identically to another SP slice or an *SI slice*.
- 3.143 **start code prefix:** A unique sequence of three *bytes* equal to 0x000001 embedded in the *byte stream* as a prefix to each *NAL unit*. 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*.
- 3.144 **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*. Within an SODB, 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.
- 3.145 **sub-macroblock:** One quarter of the samples of a *macroblock*, i.e., an 8x8 *luma block* and two corresponding *chroma blocks* of which one corner is located at a corner of the *macroblock*.
- 3.146 **sub-macroblock partition:** A *block* of *luma* samples and two corresponding *blocks* of *chroma* samples resulting from a *partitioning* of a *sub-macroblock* for *inter prediction*.
- 3.147 **switching I slice:** See *SI slice*.
- 3.148 **switching P slice:** See *SP slice*.
- 3.149 **syntax element:** An element of data represented in the *bitstream*.
- 3.150 **syntax structure:** Zero or more *syntax elements* present together in the *bitstream* in a specified order.
- 3.151 **top field:** One of two *fields* that comprise a *frame*. Each row of a *top field* is spatially located immediately above the corresponding row of the *bottom field*.
- 3.152 **top macroblock (of a macroblock pair):** The *macroblock* within a *macroblock pair* that contains the samples in the top row of samples for the *macroblock pair*. For a *field macroblock pair*, the top macroblock represents the samples from the region of the *top field* of the *frame* that lie within the spatial region of the *macroblock pair*. For a *frame macroblock pair*, the top macroblock represents the samples of the *frame* that lie within the top half of the spatial region of the *macroblock pair*.
- 3.153 **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*.

- 3.154 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.
- 3.155 universal unique identifier (UUID):** An identifier that is unique with respect to the space of all universal unique identifiers.
- 3.156 unspecified:** The term unspecified, when used in the clauses specifying some values of a particular *syntax element*, indicates that the values have no specified meaning in this Recommendation | International Standard and will not have a specified meaning in the future as an integral part of this Recommendation | International Standard.
- 3.157 variable length coding (VLC):** A reversible procedure for entropy coding that assigns shorter bit strings to *symbols* expected to be more frequent and longer bit strings to *symbols* expected to be less frequent.
- 3.158 zig-zag scan:** A specific sequential ordering of *transform coefficient levels* from (approximately) the lowest spatial frequency to the highest. Zig-zag scan is used for *transform coefficient levels* in *frame macroblocks*.

4 Abbreviations

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

CABAC	Context-based Adaptive Binary Arithmetic Coding
CAVLC	Context-based Adaptive Variable Length Coding
CBR	Constant Bit Rate
CPB	Coded Picture Buffer
DPB	Decoded Picture Buffer
DUT	Decoder under test
FIFO	First-In, First-Out
HRD	Hypothetical Reference Decoder
HSS	Hypothetical Stream Scheduler
IDR	Instantaneous Decoding Refresh
LSB	Least Significant Bit
MB	Macroblock
MBAFF	Macroblock-Adaptive Frame-Field Coding
MSB	Most Significant Bit
NAL	Network Abstraction Layer
RBSP	Raw Byte Sequence Payload
SEI	Supplemental Enhancement Information
SODB	String Of Data Bits
UUID	Universal Unique Identifier
VBR	Variable Bit Rate
VCL	Video Coding Layer
VLC	Variable Length Coding
VUI	Video Usability Information

5 Conventions

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

5.1 Arithmetic operators

The following arithmetic operators are defined as follows.

+	Addition
−	Subtraction (as a two-argument operator) or negation (as a unary prefix operator)
*	Multiplication
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 $x \geq 0$ and $y > 0$.

When order of precedence is not indicated explicitly by use of parenthesis, the following rules apply:

- multiplication and division operations are considered to take place before addition and subtraction;
- multiplication and division operations in sequence are evaluated sequentially from left to right;
- addition and subtraction operations in sequence are evaluated sequentially from left to right.

5.2 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

5.3 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.

5.4 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.
$x \gg y$	Arithmetic right shift of a two's complement integer representation of x by y binary digits. This function is defined only for positive integer values of y . Bits shifted into the MSBs as a result of the right shift have a value equal to the MSB of x prior to the shift operation.
$x \ll y$	Arithmetic left shift of a two's complement integer representation of x by y binary digits. This function is defined only for positive integer values of y . Bits shifted into the LSBs as a result of the left shift have a value equal to 0.

5.5 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 $x = x - (-3)$.

5.6 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.

5.7 Mathematical functions

The following mathematical functions are defined as follows:

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

$$\text{Ceil}(x) \quad \text{the smallest integer greater than or equal to } x. \quad (5-2)$$

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

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

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

$$\text{Floor}(x) \quad \text{the greatest integer less than or equal to } x. \quad (5-6)$$

$$\text{InverseRasterScan}(a, b, c, d, e) = \begin{cases} (a \% (d/b)) * b; & e = 0 \\ (a / (d/b)) * c; & e = 1 \end{cases} \quad (5-7)$$

$\text{Log}_2(x)$ returns the base-2 logarithm of x . (5-8)

$\text{Log}_{10}(x)$ returns the base-10 logarithm of x . (5-9)

$\text{Median}(x, y, z) = x + y + z - \text{Min}(x, \text{Min}(y, z)) - \text{Max}(x, \text{Max}(y, z))$ (5-10)

$$\text{Min}(x, y) = \begin{cases} x & ; \quad x \leq y \\ y & ; \quad x > y \end{cases}$$
 (5-11)

$$\text{Max}(x, y) = \begin{cases} x & ; \quad x \geq y \\ y & ; \quad x < y \end{cases}$$
 (5-12)

$\text{Round}(x) = \text{Sign}(x) * \text{Floor}(\text{Abs}(x) + 0.5)$ (5-13)

$$\text{Sign}(x) = \begin{cases} 1 & ; \quad x \geq 0 \\ -1 & ; \quad x < 0 \end{cases}$$
 (5-14)

$\text{Sqrt}(x) = \sqrt{x}$ (5-15)

5.8 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), its one or two syntax categories, and one or two descriptors 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 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 are described by their names, which are constructed as syntax element names, 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).

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} .

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 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 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 other value different than zero.

5.9 Text description of logical operations

In the text, a statement of logical operations as would be described in pseudo-code as

```
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 in pseudo-code as

```
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 any 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 in pseudo-code as

```
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
```

5.10 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 the 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.

The assignment of variables is specified as follows.

- If invoking a process, variables are explicitly assigned to lower case input or output variables of the process specification in case these do not have the same name.
- Otherwise (when the variables at the invoking and specification have the same name), assignment is implied.

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

6 Source, coded, decoded and output data formats, 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 Recommendation | International Standard. 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 frames and fields that is given via the bitstream.

The video source that is represented by the bitstream is a sequence of either or both frames or fields (called collectively pictures) in decoding order.

The source and decoded pictures (frames or fields) are each comprised of one or more sample arrays:

- Luma (Y) only (monochrome), with or without an auxiliary array.
- Luma and two Chroma (YCbCr or YCgCo), with or without an auxiliary array.
- Green, Blue and Red (GBR, also known as RGB), with or without an auxiliary array.

- Arrays representing other unspecified monochrome or tri-stimulus colour samplings (for example, YZX, also known as XYZ), with or without an auxiliary array.

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 (monochrome) auxiliary arrays, which may or may not be present as auxiliary pictures in a coded video sequence, are optional for decoding and can be used for such purposes as alpha blending.

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. An entry marked as "-" in Table 6-1 denotes an undefined value for SubWidthC or SubHeightC. 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

chroma_format_idc	Chroma Format	SubWidthC	SubHeightC
0	monochrome	–	–
1	4:2:0	2	2
2	4:2:2	2	1
3	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, each of the two chroma arrays has the same height and width as the luma array.

The width and height of the luma sample arrays are each an integer multiple of 16. In bitstreams using 4:2:0 chroma sampling, the width and height of chroma sample arrays are each an integer multiple of 8. In bitstreams using 4:2:2 sampling, the width of the chroma sample arrays is an integer multiple of 8 and the height is an integer multiple of 16. The height of a luma array that is coded as two separate fields or in macroblock-adaptive frame-field coding (see below) is an integer multiple of 32. In bitstreams using 4:2:0 chroma sampling, the height of each chroma array that is coded as two separate fields or in macroblock-adaptive frame-field coding (see below) is an integer multiple of 16. The width or height of pictures output from the decoding process need not be an integer multiple of 16 and can be specified using a cropping rectangle.

The syntax for the luma and (when present) chroma arrays are ordered such when data for all three colour components is present, the data for the luma array is first, followed by any data for the Cb array, followed by any data for the Cr array, unless otherwise specified.

The width of fields coded referring to a specific sequence parameter set is the same as that of frames coded referring to the same sequence parameter set (see below). The height of fields coded referring to a specific sequence parameter set is half that of frames coded referring to the same sequence parameter set (see below).

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 12, 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 frames are shown in Figure 6-1. Alternative chroma sample relative locations may be indicated in video usability information (see Annex E).

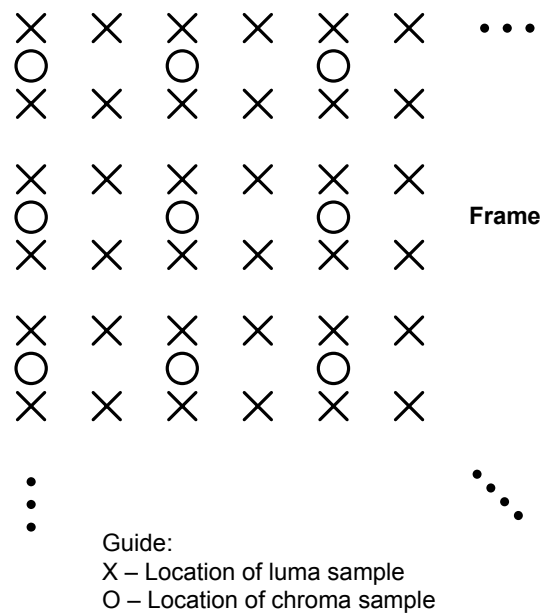


Figure 6-1 – Nominal vertical and horizontal locations of 4:2:0 luma and chroma samples in a frame

A frame consists of two fields as described below. A coded picture may represent a coded frame or an individual coded field. A coded video sequence conforming to this Recommendation | International Standard may contain arbitrary combinations of coded frames and coded fields. The decoding process is also specified in a manner that allows smaller regions of a coded frame to be coded either as a frame or field region, by use of macroblock-adaptive frame-field coding.

Source and decoded fields are one of two types: top field or bottom field. When two fields are output at the same time, or are combined to be used as a reference frame (see below), the two fields (which shall be of opposite parity) are interleaved. The first (i.e., top), third, fifth, etc. rows of a decoded frame are the top field rows. The second, fourth, sixth, etc. rows of a decoded frame are the bottom field rows. A top field consists of only the top field rows of a decoded frame. When the top field or bottom field of a decoded frame is used as a reference field (see below) only the even rows (for a top field) or the odd rows (for a bottom field) of the decoded frame are used.

When the value of chroma_format_idc is equal to 1, the nominal vertical and horizontal relative locations of luma and chroma samples in top and bottom fields are shown in Figure 6-2. The nominal vertical sampling relative locations of the chroma samples in a top field are specified as shifted up by one-quarter luma sample height relative to the field-sampling grid. The vertical sampling locations of the chroma samples in a bottom field are specified as shifted down by one-quarter luma sample height relative to the field-sampling grid. Alternative chroma sample relative locations may be indicated in the video usability information (see Annex E).

NOTE – The shifting of the chroma samples is in order for these samples to align vertically to the usual location relative to the full-frame sampling grid as shown in Figure 6-1.

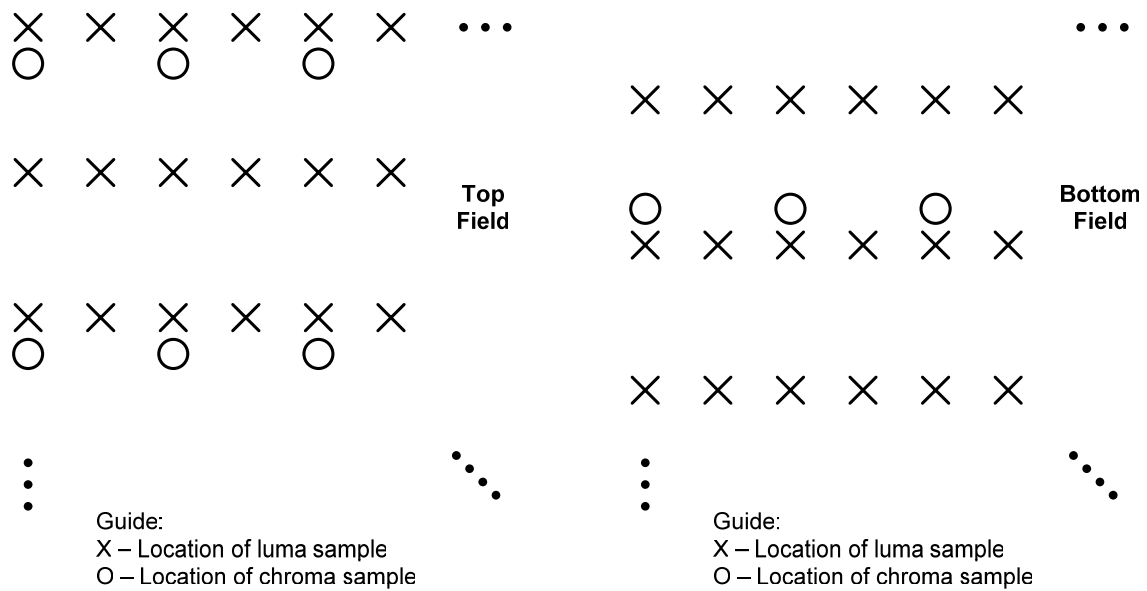


Figure 6-2 – Nominal vertical and horizontal sampling locations of 4:2:0 samples in top and bottom fields

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 frame and in fields are as shown in Figure 6-3 – Nominal vertical and horizontal locations of 4:2:2 luma and chroma samples in a frame and Figure 6-4, respectively.

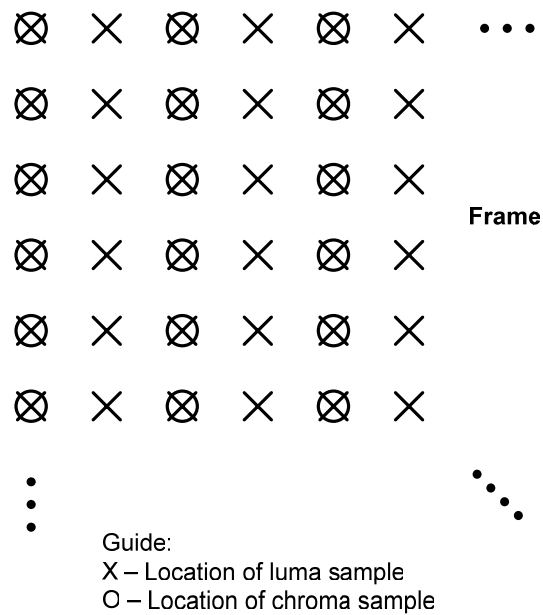


Figure 6-3 – Nominal vertical and horizontal locations of 4:2:2 luma and chroma samples in a frame

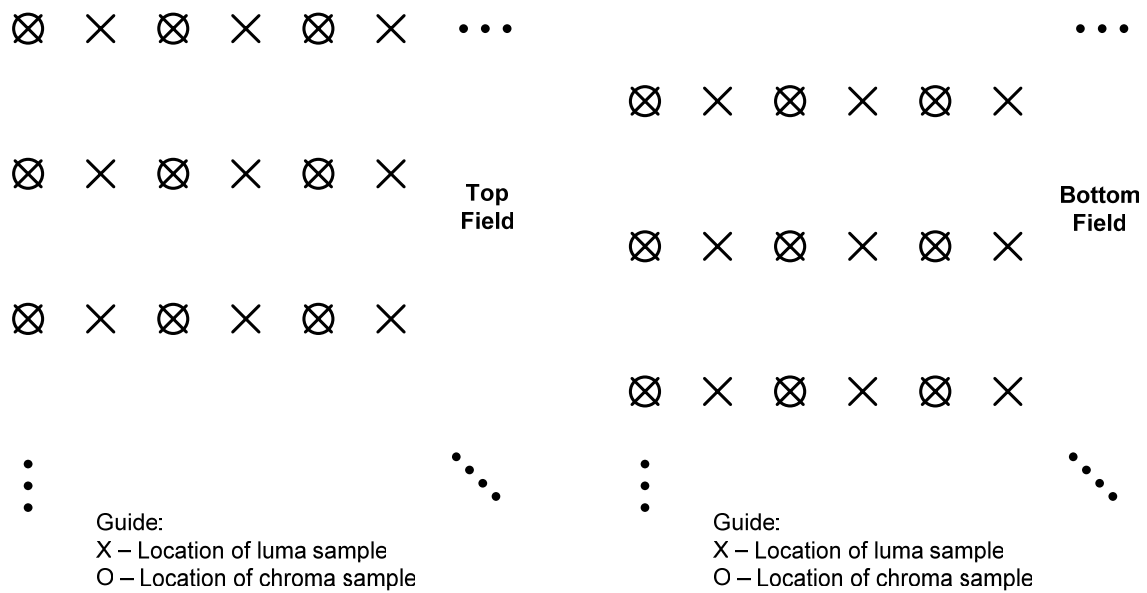


Figure 6-4 – Nominal vertical and horizontal sampling locations of 4:2:2 samples top and bottom fields

When the value of chroma_format_idc is equal to 3, all array samples are co-sited for all cases of frames and fields and the nominal locations in a frame and in fields are as shown in Figures 6-5 and 6-6, respectively.

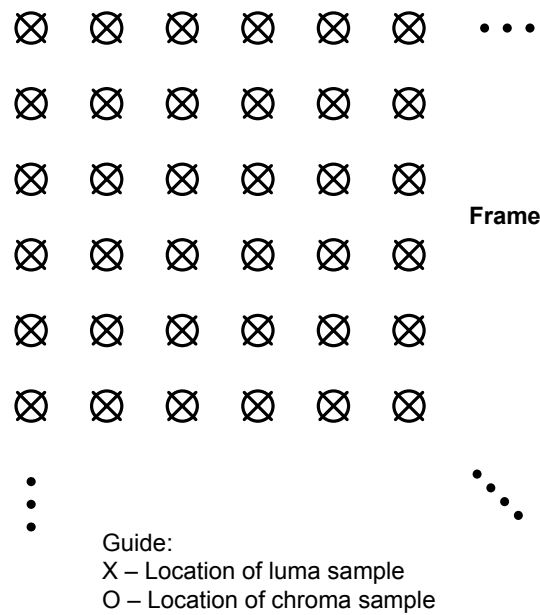


Figure 6-5 – Nominal vertical and horizontal locations of 4:4:4 luma and chroma samples in a frame

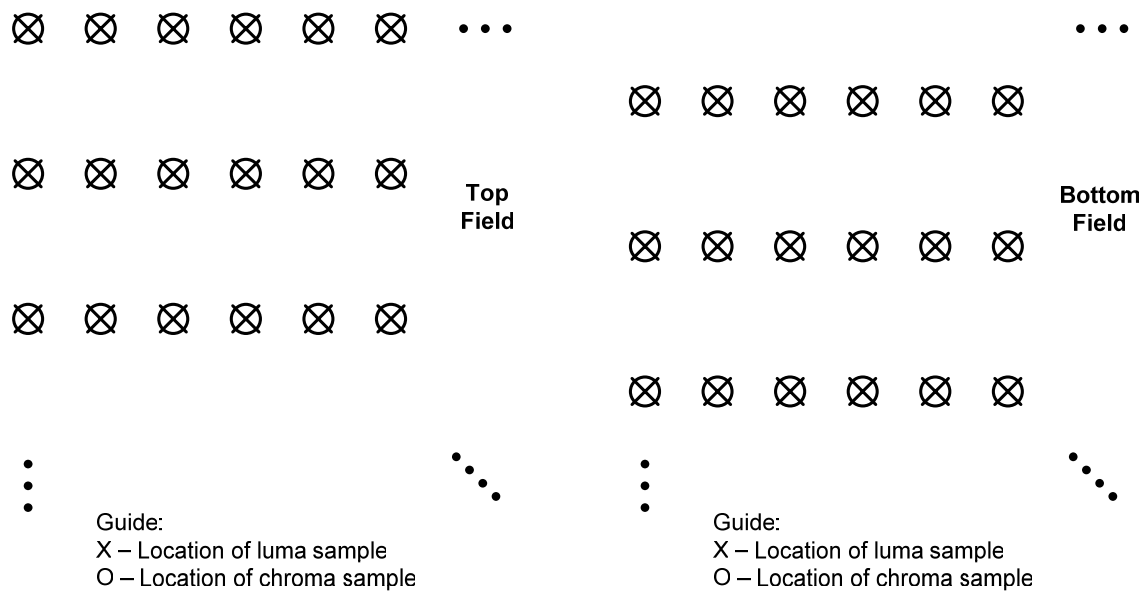


Figure 6-6 – Nominal vertical and horizontal sampling locations of 4:4:4 samples top and bottom fields

The samples are processed in units of macroblocks. The luma array for each macroblock is 16 samples in both width and height. The variables MbWidthC and MbHeightC, which specify the width and height, respectively, of the chroma arrays for each macroblock, are derived as follows.

- If chroma_format_idc is equal to 0 (monochrome), MbWidthC and MbHeightC are both equal to 0 (as no chroma arrays are specified for monochrome video).
- Otherwise, MbWidthC and MbHeightC are derived as

$$\text{MbWidthC} = 16 / \text{SubWidthC} \quad (6-1)$$

$$\text{MbHeightC} = 16 / \text{SubHeightC} \quad (6-2)$$

6.3 Spatial subdivision of pictures and slices

This subclause specifies how a picture is partitioned into slices and macroblocks. Pictures are divided into slices. A slice is a sequence of macroblocks, or, when macroblock-adaptive frame/field decoding is in use, a sequence of macroblock pairs.

Each macroblock is comprised of one 16x16 luma array and, when the video format is not monochrome, two corresponding chroma sample arrays. When macroblock-adaptive frame/field decoding is not in use, each macroblock represents a spatial rectangular region of the picture. For example, a picture may be divided into two slices as shown in Figure 6-7.

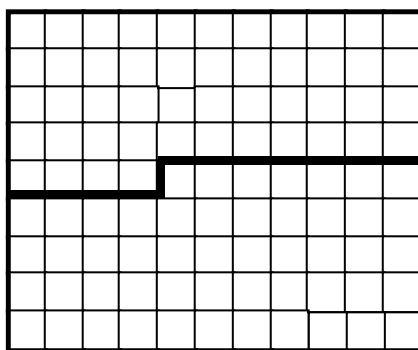


Figure 6-7 – A picture with 11 by 9 macroblocks that is partitioned into two slices

When macroblock-adaptive frame/field decoding is in use, the picture is partitioned into slices containing an integer number of macroblock pairs as shown in Figure 6-8. Each macroblock pair consists of two macroblocks.

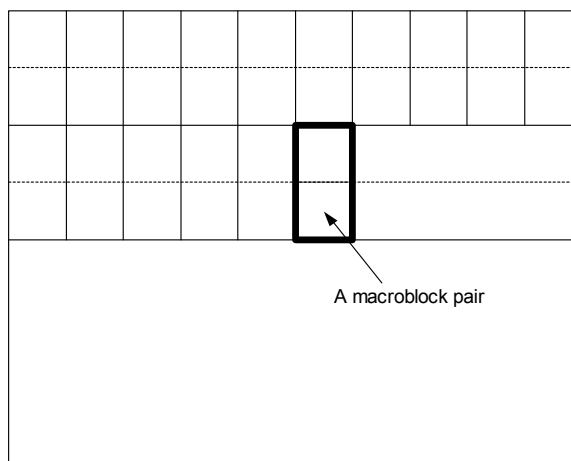


Figure 6-8 – Partitioning of the decoded frame into macroblock pairs

6.4 Inverse scanning processes and derivation processes for neighbours

This subclause specifies inverse scanning processes; i.e., the mapping of indices to locations, and derivation processes for neighbours.

6.4.1 Inverse macroblock scanning process

Input to this process is a macroblock address mbAddr.

Output of this process is the location (x, y) of the upper-left luma sample for the macroblock with address mbAddr relative to the upper-left sample of the picture.

The inverse macroblock scanning process is specified as follows.

- If MbaffFrameFlag is equal to 0,

$$x = \text{InverseRasterScan}(\text{mbAddr}, 16, 16, \text{PicWidthInSamples}_L, 0) \quad (6-3)$$

$$y = \text{InverseRasterScan}(\text{mbAddr}, 16, 16, \text{PicWidthInSamples}_L, 1) \quad (6-4)$$

- Otherwise (MbaffFrameFlag is equal to 1), the following applies.

$$xO = \text{InverseRasterScan}(\text{mbAddr} / 2, 16, 32, \text{PicWidthInSamples}_L, 0) \quad (6-5)$$

$$yO = \text{InverseRasterScan}(\text{mbAddr} / 2, 16, 32, \text{PicWidthInSamples}_L, 1) \quad (6-6)$$

Depending on the current macroblock the following applies.

- If the current macroblock is a frame macroblock

$$x = xO \quad (6-7)$$

$$y = yO + (\text{mbAddr} \% 2) * 16 \quad (6-8)$$

- Otherwise (the current macroblock is a field macroblock),

$$x = xO \quad (6-9)$$

$$y = yO + (\text{mbAddr} \% 2) \quad (6-10)$$

6.4.2 Inverse macroblock partition and sub-macroblock partition scanning process

Macroblocks or sub-macroblocks may be partitioned, and the partitions are scanned for inter prediction as shown in Figure 6-9. The outer rectangles refer to the samples in a macroblock or sub-macroblock, respectively. The rectangles refer to the partitions. The number in each rectangle specifies the index of the inverse macroblock partition scan or inverse sub-macroblock partition scan.

The functions MbPartWidth(), MbPartHeight(), SubMbPartWidth(), and SubMbPartHeight() describing the width and height of macroblock partitions and sub-macroblock partitions are specified in Tables 7-13, 7-14, 7-17, and 7-18. MbPartWidth() and MbPartHeight() are set to appropriate values for each macroblock, depending on the macroblock type. SubMbPartWidth() and SubMbPartHeight() are set to appropriate values for each sub-macroblock of a macroblock with mb_type equal to P_8x8, P_8x8ref0, or B_8x8, depending on the sub-macroblock type.

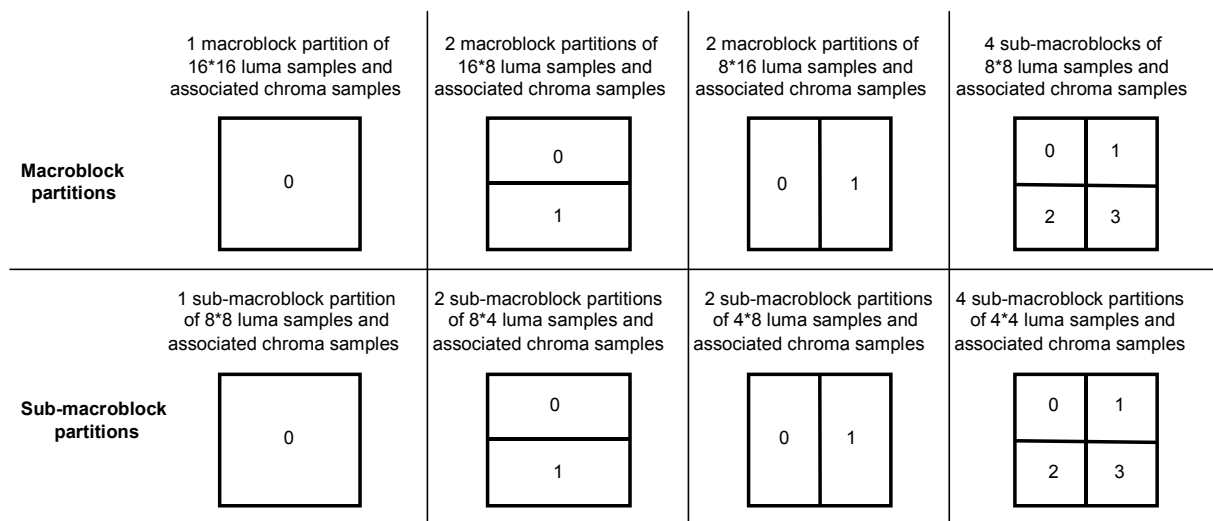


Figure 6-9 – Macroblock partitions, sub-macroblock partitions, macroblock partition scans, and sub-macroblock partition scans

6.4.2.1 Inverse macroblock partition scanning process

Input to this process is the index of a macroblock partition $mbPartIdx$.

Output of this process is the location (x, y) of the upper-left luma sample for the macroblock partition $mbPartIdx$ relative to the upper-left sample of the macroblock.

The inverse macroblock partition scanning process is specified by

$$x = \text{InverseRasterScan}(mbPartIdx, MbPartWidth(mb_type), MbPartHeight(mb_type), 16, 0) \quad (6-11)$$

$$y = \text{InverseRasterScan}(mbPartIdx, MbPartWidth(mb_type), MbPartHeight(mb_type), 16, 1) \quad (6-12)$$

6.4.2.2 Inverse sub-macroblock partition scanning process

Inputs to this process are the index of a macroblock partition $mbPartIdx$ and the index of a sub-macroblock partition $subMbPartIdx$.

Output of this process is the location (x, y) of the upper-left luma sample for the sub-macroblock partition $subMbPartIdx$ relative to the upper-left sample of the sub-macroblock.

The inverse sub-macroblock partition scanning process is specified as follows.

- If mb_type is equal to P_8x8 , $P_8x8ref0$, or B_8x8 ,

$$x = \text{InverseRasterScan}(subMbPartIdx, \text{SubMbPartWidth}(sub_mb_type[mbPartIdx]), \text{SubMbPartHeight}(sub_mb_type[mbPartIdx]), 8, 0) \quad (6-13)$$

$$y = \text{InverseRasterScan}(subMbPartIdx, \text{SubMbPartWidth}(sub_mb_type[mbPartIdx]), \text{SubMbPartHeight}(sub_mb_type[mbPartIdx]), 8, 1) \quad (6-14)$$

- Otherwise,

$$x = \text{InverseRasterScan}(subMbPartIdx, 4, 4, 8, 0) \quad (6-15)$$

$$y = \text{InverseRasterScan}(subMbPartIdx, 4, 4, 8, 1) \quad (6-16)$$

6.4.3 Inverse 4x4 luma block scanning process

Input to this process is the index of a 4x4 luma block `luma4x4BlkIdx`.

Output of this process is the location (`x`, `y`) of the upper-left luma sample for the 4x4 luma block with index `luma4x4BlkIdx` relative to the upper-left luma sample of the macroblock.

Figure 6-10 shows the scan for the 4x4 luma blocks.

0	1	4	5
2	3	6	7
8	9	12	13
10	11	14	15

Figure 6-10 – Scan for 4x4 luma blocks

The inverse 4x4 luma block scanning process is specified by

$$x = \text{InverseRasterScan}(\text{luma4x4BlkIdx} / 4, 8, 8, 16, 0) + \text{InverseRasterScan}(\text{luma4x4BlkIdx} \% 4, 4, 4, 8, 0) \quad (6-17)$$

$$y = \text{InverseRasterScan}(\text{luma4x4BlkIdx} / 4, 8, 8, 16, 1) + \text{InverseRasterScan}(\text{luma4x4BlkIdx} \% 4, 4, 4, 8, 1) \quad (6-18)$$

6.4.4 Inverse 8x8 luma block scanning process

Input to this process is the index of an 8x8 luma block `luma8x8BlkIdx`.

Output of this process is the location (`x`, `y`) of the upper-left luma sample for the 8x8 luma block with index `luma8x8BlkIdx` relative to the upper-left luma sample of the macroblock.

Figure 6-11 shows the scan for the 8x8 luma blocks.

0	1
2	3

Figure 6-11 – Scan for 8x8 luma blocks

The inverse 8x8 luma block scanning process is specified by

$$x = \text{InverseRasterScan}(\text{luma8x8BlkIdx}, 8, 8, 16, 0) \quad (6-19)$$

$$y = \text{InverseRasterScan}(\text{luma8x8BlkIdx}, 8, 8, 16, 1) \quad (6-20)$$

6.4.5 Derivation process of the availability for macroblock addresses

Input to this process is a macroblock address `mbAddr`.

Output of this process is the availability of the macroblock `mbAddr`.

NOTE – The meaning of availability is determined when this process is invoked.

The macroblock is marked as available, unless one of the following conditions is true in which case the macroblock is marked as not available:

- $mbAddr < 0$
- $mbAddr > CurrMbAddr$
- the macroblock with address $mbAddr$ belongs to a different slice than the macroblock with address $CurrMbAddr$

6.4.6 Derivation process for neighbouring macroblock addresses and their availability

This process can only be invoked when $MbaffFrameFlag$ is equal to 0.

The outputs of this process are

- $mbAddrA$: the address and availability status of the macroblock to the left of the current macroblock.
- $mbAddrB$: the address and availability status of the macroblock above the current macroblock.
- $mbAddrC$: the address and availability status of the macroblock above-right of the current macroblock.
- $mbAddrD$: the address and availability status of the macroblock above-left of the current macroblock.

Figure 6-12 shows the relative spatial locations of the macroblocks with $mbAddrA$, $mbAddrB$, $mbAddrC$, and $mbAddrD$ relative to the current macroblock with $CurrMbAddr$.

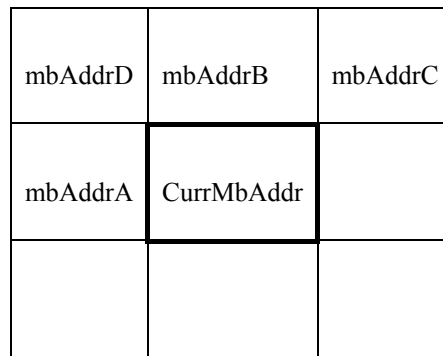


Figure 6-12 – Neighbouring macroblocks for a given macroblock

Input to the process in subclause 6.4.5 is $mbAddrA = CurrMbAddr - 1$ and the output is whether the macroblock $mbAddrA$ is available. In addition, $mbAddrA$ is marked as not available when $CurrMbAddr \% PicWidthInMbs$ is equal to 0.

Input to the process in subclause 6.4.5 is $mbAddrB = CurrMbAddr - PicWidthInMbs$ and the output is whether the macroblock $mbAddrB$ is available.

Input to the process in subclause 6.4.5 is $mbAddrC = CurrMbAddr - PicWidthInMbs + 1$ and the output is whether the macroblock $mbAddrC$ is available. In addition, $mbAddrC$ is marked as not available when $(CurrMbAddr + 1) \% PicWidthInMbs$ is equal to 0.

Input to the process in subclause 6.4.5 is $mbAddrD = CurrMbAddr - PicWidthInMbs - 1$ and the output is whether the macroblock $mbAddrD$ is available. In addition, $mbAddrD$ is marked as not available when $CurrMbAddr \% PicWidthInMbs$ is equal to 0.

6.4.7 Derivation process for neighbouring macroblock addresses and their availability in MBAFF frames

This process can only be invoked when $MbaffFrameFlag$ is equal to 1.

The outputs of this process are

- $mbAddrA$: the address and availability status of the top macroblock of the macroblock pair to the left of the current macroblock pair.
- $mbAddrB$: the address and availability status of the top macroblock of the macroblock pair above the current macroblock pair.

- mbAddrC: the address and availability status of the top macroblock of the macroblock pair above-right of the current macroblock pair.
- mbAddrD: the address and availability status of the top macroblock of the macroblock pair above-left of the current macroblock pair.

Figure 6-13 shows the relative spatial locations of the macroblocks with mbAddrA, mbAddrB, mbAddrC, and mbAddrD relative to the current macroblock with CurrMbAddr.

mbAddrA, mbAddrB, mbAddrC, and mbAddrD have identical values regardless whether the current macroblock is the top or the bottom macroblock of a macroblock pair.

mbAddrD	mbAddrB	mbAddrC
mbAddrA	CurrMbAddr or CurrMbAddr	

Figure 6-13 – Neighbouring macroblocks for a given macroblock in MBAFF frames

Input to the process in subclause 6.4.5 is $mbAddrA = 2 * (CurrMbAddr / 2 - 1)$ and the output is whether the macroblock mbAddrA is available. In addition, mbAddrA is marked as not available when $(CurrMbAddr / 2) \% PicWidthInMbs$ is equal to 0.

Input to the process in subclause 6.4.5 is $mbAddrB = 2 * (CurrMbAddr / 2 - PicWidthInMbs)$ and the output is whether the macroblock mbAddrB is available.

Input to the process in subclause 6.4.5 is $mbAddrC = 2 * (CurrMbAddr / 2 - PicWidthInMbs + 1)$ and the output is whether the macroblock mbAddrC is available. In addition, mbAddrC is marked as not available when $(CurrMbAddr / 2 + 1) \% PicWidthInMbs$ is equal to 0.

Input to the process in subclause 6.4.5 is $mbAddrD = 2 * (CurrMbAddr / 2 - PicWidthInMbs - 1)$ and the output is whether the macroblock mbAddrD is available. In addition, mbAddrD is marked as not available when $(CurrMbAddr / 2) \% PicWidthInMbs$ is equal to 0.

6.4.8 Derivation processes for neighbouring macroblocks, blocks, and partitions

Subclause 6.4.8.1 specifies the derivation process for neighbouring macroblocks.

Subclause 6.4.8.2 specifies the derivation process for neighbouring 8x8 luma blocks.

Subclause 6.4.8.3 specifies the derivation process for neighbouring 4x4 luma blocks.

Subclause 6.4.8.4 specifies the derivation process for neighbouring 4x4 chroma blocks.

Subclause 6.4.8.5 specifies the derivation process for neighbouring partitions.

Table 6-2 specifies the values for the difference of luma location (xD, yD) for the input and the replacement for N in mbAddrN, mbPartIdxN, subMbPartIdxN, luma8x8BlkIdxN, luma4x4BlkIdxN, and chroma4x4BlkIdxN for the output. These input and output assignments are used in subclauses 6.4.8.1 to 6.4.8.5. The variable predPartWidth is specified when Table 6-2 is referred to.

Table 6-2 – Specification of input and output assignments for subclauses 6.4.8.1 to 6.4.8.5

N	x _D	y _D
A	-1	0
B	0	-1
C	predPartWidth	-1
D	-1	-1

Figure 6-14 illustrates the relative location of the neighbouring macroblocks, blocks, or partitions A, B, C, and D to the current macroblock, partition, or block, when the current macroblock, partition, or block is in frame coding mode.

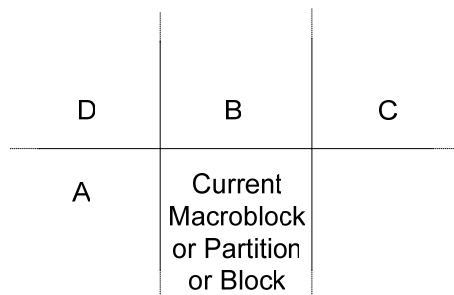


Figure 6-14 – Determination of the neighbouring macroblock, blocks, and partitions (informative)

6.4.8.1 Derivation process for neighbouring macroblocks

Outputs of this process are

- mbAddrA: the address of the macroblock to the left of the current macroblock and its availability status and
- mbAddrB: the address of the macroblock above the current macroblock and its availability status.
- mbAddrN (with N being A or B) is derived as follows.
- The difference of luma location (x_D, y_D) is set according to Table 6-2.
- The derivation process for neighbouring locations as specified in subclause 6.4.9 is invoked for luma locations with (x_N, y_N) equal to (x_D, y_D), and the output is assigned to mbAddrN.

6.4.8.2 Derivation process for neighbouring 8x8 luma block

Input to this process is an 8x8 luma block index luma8x8BlkIdx.

The luma8x8BlkIdx specifies the 8x8 luma blocks of a macroblock in a raster scan.

Outputs of this process are

- mbAddrA: either equal to CurrMbAddr or the address of the macroblock to the left of the current macroblock and its availability status,
- luma8x8BlkIdxA: the index of the 8x8 luma block to the left of the 8x8 block with index luma8x8BlkIdx and its availability status,
- mbAddrB: either equal to CurrMbAddr or the address of the macroblock above the current macroblock and its availability status,
- luma8x8BlkIdxB: the index of the 8x8 luma block above the 8x8 block with index luma8x8BlkIdx and its availability status.

mbAddrN and luma8x8BlkIdxN (with N being A or B) are derived as follows.

- The difference of luma location (xD, yD) is set according to Table 6-2.
- The luma location (xN, yN) is specified by

$$xN = (luma8x8BlkIdx \% 2) * 8 + xD \quad (6-21)$$

$$yN = (luma8x8BlkIdx / 2) * 8 + yD \quad (6-22)$$

- The derivation process for neighbouring locations as specified in subclause 6.4.9 is invoked for luma locations with (xN, yN) as the input and the output is assigned to mbAddrN and (xW, yW).
- The variable luma8x8BlkIdxN is derived as follows.
 - If mbAddrN is not available, luma8x8BlkIdxN is marked as not available.
 - Otherwise (mbAddrN is available), the 8x8 luma block in the macroblock mbAddrN covering the luma location (xW, yW) is assigned to luma8x8BlkIdxN.

6.4.8.3 Derivation process for neighbouring 4x4 luma blocks

Input to this process is a 4x4 luma block index luma4x4BlkIdx.

Outputs of this process are

- mbAddrA: either equal to CurrMbAddr or the address of the macroblock to the left of the current macroblock and its availability status,
- luma4x4BlkIdxA: the index of the 4x4 luma block to the left of the 4x4 block with index luma4x4BlkIdx and its availability status,
- mbAddrB: either equal to CurrMbAddr or the address of the macroblock above the current macroblock and its availability status,
- luma4x4BlkIdxB: the index of the 4x4 luma block above the 4x4 block with index luma4x4BlkIdx and its availability status.

mbAddrN and luma4x4BlkIdxN (with N being A or B) are derived as follows.

- The difference of luma location (xD, yD) is set according to Table 6-2.
- The inverse 4x4 luma block scanning process as specified in subclause 6.4.3 is invoked with luma4x4BlkIdx as the input and (x, y) as the output.
- The luma location (xN, yN) is specified by

$$xN = x + xD \quad (6-23)$$

$$yN = y + yD \quad (6-24)$$

- The derivation process for neighbouring locations as specified in subclause 6.4.9 is invoked for luma locations with (xN, yN) as the input and the output is assigned to mbAddrN and (xW, yW).
- The variable luma4x4BlkIdxN is derived as follows.
 - If mbAddrN is not available, luma4x4BlkIdxN is marked as not available.
 - Otherwise (mbAddrN is available), the 4x4 luma block in the macroblock mbAddrN covering the luma location (xW, yW) is assigned to luma4x4BlkIdxN.

6.4.8.4 Derivation process for neighbouring 4x4 chroma blocks

Input to this process is a 4x4 chroma block index chroma4x4BlkIdx.

Outputs of this process are

- mbAddrA (either equal to CurrMbAddr or the address of the macroblock to the left of the current macroblock) and its availability status,
- chroma4x4BlkIdxA (the index of the 4x4 chroma block to the left of the 4x4 chroma block with index chroma4x4BlkIdx) and its availability status,

- mbAddrB (either equal to CurrMbAddr or the address of the macroblock above the current macroblock) and its availability status,
- chroma4x4BlkIdxB (the index of the 4x4 chroma block above the 4x4 chroma block with index chroma4x4BlkIdx) and its availability status.

mbAddrN and chroma4x4BlkIdxN (with N being A or B) are derived as follows.

- The difference of chroma location (xD, yD) is set according to Table 6-2.
- Depending on chroma_format_idc, the position (x, y) of the upper-left sample of the 4x4 chroma block with index chroma4x4BlkIdx is derived as follows

- If chroma_format_idc is equal to 1 or 2, the following applies

$$x = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 0) \quad (6-25)$$

$$y = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 1) \quad (6-26)$$

- Otherwise (chroma_format_idc is equal to 3), the following applies

$$x = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 0) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 0) \quad (6-27)$$

$$y = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 1) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 1) \quad (6-28)$$

- The chroma location (xN, yN) is specified by

$$xN = x + xD \quad (6-29)$$

$$yN = y + yD \quad (6-30)$$

- The derivation process for neighbouring locations as specified in subclause 6.4.9 is invoked for chroma locations with (xN, yN) as the input and the output is assigned to mbAddrN and (xW, yW).
- The variable chroma4x4BlkIdxN is derived as follows.
 - If mbAddrN is not available, chroma4x4BlkIdxN is marked as not available.
 - Otherwise (mbAddrN is available), the 4x4 chroma block in the macroblock mbAddrN covering the chroma location (xW, yW) is assigned to chroma4x4BlkIdxN.

6.4.8.5 Derivation process for neighbouring partitions

Inputs to this process are

- a macroblock partition index mbPartIdx
- a current sub-macroblock type currSubMbType
- a sub-macroblock partition index subMbPartIdx

Outputs of this process are

- mbAddrA\mbPartIdxA\subMbPartIdxA: specifying the macroblock or sub-macroblock partition to the left of the current macroblock and its availability status, or the sub-macroblock partition CurrMbAddr\mbPartIdx\subMbPartIdx and its availability status,

- mbAddrB\mbPartIdxB\subMbPartIdxB: specifying the macroblock or sub-macroblock partition above the current macroblock and its availability status, or the sub-macroblock partition CurrMbAddr\mbPartIdx\subMbPartIdx and its availability status,
- mbAddrC\mbPartIdxC\subMbPartIdxC: specifying the macroblock or sub-macroblock partition to the right-above of the current macroblock and its availability status, or the sub-macroblock partition CurrMbAddr\mbPartIdx\subMbPartIdx and its availability status,
- mbAddrD\mbPartIdxD\subMbPartIdxD: specifying the macroblock or sub-macroblock partition to the left-above of the current macroblock and its availability status, or the sub-macroblock partition CurrMbAddr\mbPartIdx\subMbPartIdx and its availability status.

mbAddrN, mbPartIdxN, and subMbPartIdx (with N being A, B, C, or D) are derived as follows.

- The inverse macroblock partition scanning process as described in subclause 6.4.2.1 is invoked with mbPartIdx as the input and (x, y) as the output.
- The location of the upper-left luma sample inside a macroblock partition (xS, yS) is derived as follows.
 - If mb_type is equal to P_8x8, P_8x8ref0 or B_8x8, the inverse sub-macroblock partition scanning process as described in subclause 6.4.2.2 is invoked with subMbPartIdx as the input and (xS, yS) as the output.
 - Otherwise, (xS, yS) are set to (0, 0).
- The variable predPartWidth in Table 6-2 is specified as follows.
 - If mb_type is equal to P_Skip, B_Skip, or B_Direct_16x16, predPartWidth = 16.
 - Otherwise, if mb_type is equal to B_8x8, the following applies.
 - If currSubMbType is equal to B_Direct_8x8, predPartWidth = 16.
NOTE 1 – When currSubMbType is equal to B_Direct_8x8 and direct_spatial_mv_pred_flag is equal to 1, the predicted motion vector is the predicted motion vector for the complete macroblock.
 - Otherwise, predPartWidth = SubMbPartWidth(sub_mb_type[mbPartIdx]).
 - Otherwise, if mb_type is equal to P_8x8 or P_8x8ref0, predPartWidth = SubMbPartWidth(sub_mb_type[mbPartIdx]).
 - Otherwise, predPartWidth = MbPartWidth(mb_type).
- The difference of luma location (xD, yD) is set according to Table 6-2.
- The neighbouring luma location (xN, yN) is specified by

$$xN = x + xS + xD \quad (6-31)$$

$$yN = y + yS + yD \quad (6-32)$$

- The derivation process for neighbouring locations as specified in subclause 6.4.9 is invoked for luma locations with (xN, yN) as the input and the output is assigned to mbAddrN and (xW, yW).
- Depending on mbAddrN, the following applies.
 - If mbAddrN is not available, the macroblock or sub-macroblock partition mbAddrN\mbPartIdxN\subMbPartIdxN is marked as not available.
 - Otherwise (mbAddrN is available), the following applies.
 - The macroblock partition in the macroblock mbAddrN covering the luma location (xW, yW) is assigned to mbPartIdxN and the sub-macroblock partition inside the macroblock partition mbPartIdxN covering the sample (xW, yW) in the macroblock mbAddrN is assigned to subMbPartIdxN.
 - When the partition given by mbPartIdxN and subMbPartIdxN is not yet decoded, the macroblock partition mbPartIdxN and the sub-macroblock partition subMbPartIdxN are marked as not available.

NOTE 2 – The latter condition is, for example, the case when mbPartIdx = 2, subMbPartIdx = 3, xD = 4, yD = -1, i.e., when neighbour C of the last 4x4 luma block of the third sub-macroblock is requested.

6.4.9 Derivation process for neighbouring locations

Input to this process is a luma or chroma location (x_N, y_N) expressed relative to the upper left corner of the current macroblock.

Outputs of this process are

- $mbAddrN$: either equal to $CurrMbAddr$ or to the address of neighbouring macroblock that contains (x_N, y_N) and its availability status,
- (x_W, y_W): the location (x_N, y_N) expressed relative to the upper-left corner of the macroblock $mbAddrN$ (rather than relative to the upper-left corner of the current macroblock).

Let $maxW$ and $maxH$ be variables specifying maximum values of the location components x_N, x_W , and y_N, y_W , respectively. $maxW$ and $maxH$ are derived as follows.

- If this process is invoked for neighbouring luma locations,

$$maxW = maxH = 16 \quad (6-33)$$

- Otherwise (this process is invoked for neighbouring chroma locations),

$$maxW = MbWidthC \quad (6-34)$$

$$maxH = MbHeightC \quad (6-35)$$

Depending on the variable $MbaffFrameFlag$, the neighbouring locations are derived as follows.

- If $MbaffFrameFlag$ is equal to 0, the specification for neighbouring locations in fields and non-MBAFF frames as described in subclause 6.4.9.1 is applied.
- Otherwise ($MbaffFrameFlag$ is equal to 1), the specification for neighbouring locations in MBAFF frames as described in subclause 6.4.9.2 is applied.

6.4.9.1 Specification for neighbouring locations in fields and non-MBAFF frames

The specifications in this subclause are applied when $MbaffFrameFlag$ is equal to 0.

The derivation process for neighbouring macroblock addresses and their availability in subclause 6.4.6 is invoked with $mbAddrA, mbAddrB, mbAddrC$, and $mbAddrD$ as well as their availability status as the output.

Table 6-3 specifies $mbAddrN$ depending on (x_N, y_N).

Table 6-3 – Specification of $mbAddrN$

x_N	y_N	$mbAddrN$
< 0	< 0	$mbAddrD$
< 0	$0 .. maxH - 1$	$mbAddrA$
$0 .. maxW - 1$	< 0	$mbAddrB$
$0 .. maxW - 1$	$0 .. maxH - 1$	$CurrMbAddr$
$> maxW - 1$	< 0	$mbAddrC$
$> maxW - 1$	$0 .. maxH - 1$	not available
	$> maxH - 1$	not available

The neighbouring location (x_W, y_W) relative to the upper-left corner of the macroblock $mbAddrN$ is derived as

$$x_W = (x_N + maxW) \% maxW \quad (6-36)$$

$$y_W = (y_N + maxH) \% maxH \quad (6-37)$$

6.4.9.2 Specification for neighbouring locations in MBAFF frames

The specifications in this subclause are applied when MbaffFrameFlag is equal to 1.

The derivation process for neighbouring macroblock addresses and their availability in subclause 6.4.7 is invoked with mbAddrA, mbAddrB, mbAddrC, and mbAddrD as well as their availability status as the output.

Table 6-4 specifies the macroblock addresses mbAddrN and yM in two ordered steps:

1. Specification of a macroblock address mbAddrX depending on (xN, yN) and the following variables:
 - The variable currMbFrameFlag is derived as follows.
 - If the macroblock with address CurrMbAddr is a frame macroblock, currMbFrameFlag is set equal to 1,
 - Otherwise (the macroblock with address CurrMbAddr is a field macroblock), currMbFrameFlag is set equal to 0.
 - The variable mbIsTopMbFlag is derived as follows.
 - If the macroblock with address CurrMbAddr is a top macroblock (CurrMbAddr % 2 is equal to 0), mbIsTopMbFlag is set equal to 1;
 - Otherwise (the macroblock with address CurrMbAddr is a bottom macroblock, CurrMbAddr % 2 is equal to 1), mbIsTopMbFlag is set equal to 0.
2. Depending on the availability of mbAddrX, the following applies.
 - If mbAddrX is not available, mbAddrN is marked as not available.
 - Otherwise (mbAddrX is available), mbAddrN is marked as available and Table 6-4 specifies mbAddrN and yM depending on (xN, yN), currMbFrameFlag, mbIsTopMbFlag, and the variable mbAddrXFrameFlag, which is derived as follows.
 - If the macroblock mbAddrX is a frame macroblock, mbAddrXFrameFlag is set equal to 1,
 - Otherwise (the macroblock mbAddrX is a field macroblock), mbAddrXFrameFlag is set equal to 0.

Unspecified values (na) of the above flags in Table 6-4 indicate that the value of the corresponding flag is not relevant for the current table rows.

Table 6-4 – Specification of mbAddrN and yM

x_N	y_N	currMbFrameFlag	mbIsTopMbFlag	mbAddrX	mbAddrXFrameFlag	additional condition	mbAddrN	y_M	
< 0	< 0	1	1	mbAddrD			mbAddrD + 1	y_N	
			0	mbAddrA	1		mbAddrA	y_N	
		0	1	mbAddrD	1		mbAddrD + 1	$(y_N + \text{maxH}) \gg 1$	
			0	mbAddrD	0		mbAddrD	$2 * y_N$	
< 0	$0 \dots \text{maxH} - 1$	1	1	mbAddrA	1		mbAddrA	y_N	
					0	$y_N \% 2 == 0$	mbAddrA	$y_N \gg 1$	
					0	$y_N \% 2 != 0$	mbAddrA + 1	$y_N \gg 1$	
			0	mbAddrA	1	$y_N \% 2 == 0$	mbAddrA	$(y_N + \text{maxH}) \gg 1$	
					0	$y_N \% 2 != 0$	mbAddrA + 1	$(y_N + \text{maxH}) \gg 1$	
					1	$y_N < (\text{maxH} / 2)$	mbAddrA	$y_N \ll 1$	
		0	mbAddrA	1	1	$y_N \geq (\text{maxH} / 2)$	mbAddrA + 1	$(y_N \ll 1) - \text{maxH}$	
					0		mbAddrA	y_N	
				0	mbAddrA	1	$y_N < (\text{maxH} / 2)$	mbAddrA	$(y_N \ll 1) + 1$
							$y_N \geq (\text{maxH} / 2)$	mbAddrA + 1	$(y_N \ll 1) + 1 - \text{maxH}$
						0		mbAddrA + 1	y_N
$0 \dots \text{maxW} - 1$	< 0	1	1	mbAddrB		mbAddrB + 1	y_N		
			0	CurrMbAddr		CurrMbAddr - 1	y_N		
		0	1	mbAddrB	1		mbAddrB + 1	$2 * y_N$	
			0	mbAddrB	0		mbAddrB	y_N	
$0 \dots \text{maxW} - 1$	$0 \dots \text{maxH} - 1$			CurrMbAddr		CurrMbAddr	y_N		
> $\text{maxW} - 1$	< 0	1	1	mbAddrC		mbAddrC + 1	y_N		
			0	not available		not available	na		
		0	1	mbAddrC	1		mbAddrC + 1	$2 * y_N$	
			0	mbAddrC	0		mbAddrC	y_N	
> $\text{maxW} - 1$	$0 \dots \text{maxH} - 1$			not available		not available	na		
	> $\text{maxH} - 1$			not available		not available	na		

The neighbouring luma location (x_W, y_W) relative to the upper-left corner of the macroblock mbAddrN is derived as

$$x_W = (x_N + \text{maxW}) \% \text{maxW} \tag{6-38}$$

$$y_W = (y_M + \text{maxH}) \% \text{maxH} \tag{6-39}$$

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 means for identifying entry points into the bitstream and means to identify and handle non-conforming bitstreams. The methods for identifying and handling errors and other such situations are not specified here.

The following table lists examples of pseudo code used to describe the syntax. 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.

	C	Descriptor
/* A statement can be a syntax element with an associated syntax category and 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	3	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, categories, and descriptors

The functions presented here are used in the syntactical description. These functions 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.

`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_rbsp_data()` is specified as follows.

- If there is more data in an RBSP before `rbsp_trailing_bits()`, 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.

`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 as specified in Annex B, `next_bits(n)` returns a value of 0 if fewer than n bits remain within the byte stream.

`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.

Categories (labelled in the table as C) specify the partitioning of slice data into at most three slice data partitions. Slice data partition A contains all syntax elements of category 2. Slice data partition B contains all syntax elements of category 3. Slice data partition C contains all syntax elements of category 4. The meaning of other category values is not specified. For some syntax elements, two category values, separated by a vertical bar, are used. In these cases, the category value to be applied is further specified in the text. For syntax structures used within other syntax structures, the categories of all syntax elements found within the included syntax structure are listed, separated by a vertical bar. A syntax element or syntax structure with category marked as "All" is present within all syntax structures that include that syntax element or syntax structure. For syntax structures used within other syntax structures, a numeric category value provided in a syntax table at the location of the inclusion of a syntax structure containing a syntax element with category marked as "All" is considered to apply to the syntax elements with category "All".

The following descriptors specify the parsing process of each syntax element. For some syntax elements, two descriptors, separated by a vertical bar, are used. In these cases, the left descriptors apply when `entropy_coding_mode_flag` is equal to 0 and the right descriptor applies when `entropy_coding_mode_flag` is equal to 1.

- `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)`.
- `ce(v)`: context-adaptive variable-length entropy-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause 9.2.
- `f(n)`: fixed-pattern bit string using n bits written (from left to right) with the left bit first. The parsing process for this descriptor is specified by the return value of the function `read_bits(n)`.
- `i(n)`: signed integer using n bits. When n is "v" in the syntax table, the number of bits varies in a manner dependent on the value of other syntax elements. The parsing process for this descriptor is specified by the

return value of the function `read_bits(n)` interpreted as a two's complement integer representation with most significant bit written first.

- `me(v)`: mapped Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause 9.1.
- `se(v)`: signed integer Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause 9.1.
- `te(v)`: truncated Exp-Golomb-coded syntax element with left bit first. The parsing process for this descriptor is specified in subclause 9.1.
- `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 Exp-Golomb-coded syntax element with the left bit first. The parsing process for this descriptor is specified in subclause 9.1.

7.3 Syntax in tabular form

7.3.1 NAL unit syntax

	C	Descriptor
<code>nal_unit(NumBytesInNALunit) {</code>		
forbidden_zero_bit	All	f(1)
nal_ref_idc	All	u(2)
nal_unit_type	All	u(5)
NumBytesInRBSP = 0		
for(i = 1; i < NumBytesInNALunit; i++) {		
if(i + 2 < NumBytesInNALunit && next_bits(24) == 0x000003) {		
rbsp_byte [NumBytesInRBSP++]	All	b(8)
rbsp_byte [NumBytesInRBSP++]	All	b(8)
i += 2		
emulation_prevention_three_byte /* equal to 0x03 */	All	f(8)
} else		
rbsp_byte [NumBytesInRBSP++]	All	b(8)
}		
}		

7.3.2 Raw byte sequence payloads and RBSP trailing bits syntax

7.3.2.1 Sequence parameter set RBSP syntax

seq_parameter_set_rbsp() {	C	Descriptor
profile_idc	0	u(8)
constraint_set0_flag	0	u(1)
constraint_set1_flag	0	u(1)
constraint_set2_flag	0	u(1)
constraint_set3_flag	0	u(1)
reserved_zero_4bits /* equal to 0 */	0	u(4)
level_idc	0	u(8)
seq_parameter_set_id	0	ue(v)
if(profile_idc == 100 profile_idc == 110 profile_idc == 122 profile_idc == 144) {		
chroma_format_idc	0	ue(v)
if(chroma_format_idc == 3)		
residual_colour_transform_flag	0	u(1)
bit_depth_luma_minus8	0	ue(v)
bit_depth_chroma_minus8	0	ue(v)
qprime_y_zero_transform_bypass_flag	0	u(1)
seq_scaling_matrix_present_flag	0	u(1)
if(seq_scaling_matrix_present_flag)		
for(i = 0; i < 8; i++) {		
seq_scaling_list_present_flag[i]	0	u(1)
if(seq_scaling_list_present_flag[i])		
if(i < 6)		
scaling_list(ScalingList4x4[i], 16, UseDefaultScalingMatrix4x4Flag[i])	0	
else		
scaling_list(ScalingList8x8[i - 6], 64, UseDefaultScalingMatrix8x8Flag[i - 6])	0	
}		
}		
log2_max_frame_num_minus4	0	ue(v)
pic_order_cnt_type	0	ue(v)
if(pic_order_cnt_type == 0)		
log2_max_pic_order_cnt_lsb_minus4	0	ue(v)
else if(pic_order_cnt_type == 1) {		
delta_pic_order_always_zero_flag	0	u(1)
offset_for_non_ref_pic	0	se(v)
offset_for_top_to_bottom_field	0	se(v)
num_ref_frames_in_pic_order_cnt_cycle	0	ue(v)
for(i = 0; i < num_ref_frames_in_pic_order_cnt_cycle; i++)		
offset_for_ref_frame[i]	0	se(v)
}		
num_ref_frames	0	ue(v)
gaps_in_frame_num_value_allowed_flag	0	u(1)
pic_width_in_mbs_minus1	0	ue(v)
pic_height_in_map_units_minus1	0	ue(v)

frame_mbs_only_flag	0	u(1)
if(!frame_mbs_only_flag)		
mb_adaptive_frame_field_flag	0	u(1)
direct_8x8_inference_flag	0	u(1)
frame_cropping_flag	0	u(1)
if(frame_cropping_flag) {		
frame_crop_left_offset	0	ue(v)
frame_crop_right_offset	0	ue(v)
frame_crop_top_offset	0	ue(v)
frame_crop_bottom_offset	0	ue(v)
}		
vui_parameters_present_flag	0	u(1)
if(vui_parameters_present_flag)		
vui_parameters()	0	
rbsp_trailing_bits()	0	
}		

7.3.2.1.1 Scaling list syntax

scaling_list(scalingList, sizeOfScalingList, useDefaultScalingMatrixFlag) {	C	Descriptor
lastScale = 8		
nextScale = 8		
for(j = 0; j < sizeOfScalingList; j++) {		
if(nextScale != 0) {		
delta_scale	0 1	se(v)
nextScale = (lastScale + delta_scale + 256) % 256		
useDefaultScalingMatrixFlag = (j == 0 && nextScale == 0)		
}		
scalingList[j] = (nextScale == 0) ? lastScale : nextScale		
lastScale = scalingList[j]		
}		
}		

7.3.2.1.2 Sequence parameter set extension RBSP syntax

seq_parameter_set_extension_rbsp() {	C	Descriptor
seq_parameter_set_id	10	ue(v)
aux_format_idc	10	ue(v)
if(aux_format_idc != 0) {		
bit_depth_aux_minus8	10	ue(v)
alpha_incr_flag	10	u(1)
alpha_opaque_value	10	u(v)
alpha_transparent_value	10	u(v)
}		
additional_extension_flag	10	u(1)
rbsp_trailing_bits()	10	
}		

7.3.2.2 Picture parameter set RBSP syntax

pic_parameter_set_rbsp() {	C	Descriptor
pic_parameter_set_id	1	ue(v)
seq_parameter_set_id	1	ue(v)
entropy_coding_mode_flag	1	u(1)
pic_order_present_flag	1	u(1)
num_slice_groups_minus1	1	ue(v)
if(num_slice_groups_minus1 > 0) {		
slice_group_map_type	1	ue(v)
if(slice_group_map_type == 0)		
for(iGroup = 0; iGroup <= num_slice_groups_minus1; iGroup++)		
run_length_minus1[iGroup]	1	ue(v)
else if(slice_group_map_type == 2)		
for(iGroup = 0; iGroup < num_slice_groups_minus1; iGroup++) {		
top_left[iGroup]	1	ue(v)
bottom_right[iGroup]	1	ue(v)
}		
else if(slice_group_map_type == 3 slice_group_map_type == 4 slice_group_map_type == 5) {		
slice_group_change_direction_flag	1	u(1)
slice_group_change_rate_minus1	1	ue(v)
} else if(slice_group_map_type == 6) {		
pic_size_in_map_units_minus1	1	ue(v)
for(i = 0; i <= pic_size_in_map_units_minus1; i++)		
slice_group_id[i]	1	u(v)
}		
}		
}		
num_ref_idx_l0_active_minus1	1	ue(v)
num_ref_idx_l1_active_minus1	1	ue(v)
weighted_pred_flag	1	u(1)
weighted_bipred_idc	1	u(2)
pic_init_qp_minus26 /* relative to 26 */	1	se(v)
pic_init_qs_minus26 /* relative to 26 */	1	se(v)
chroma_qp_index_offset	1	se(v)
deblocking_filter_control_present_flag	1	u(1)
constrained_intra_pred_flag	1	u(1)
redundant_pic_cnt_present_flag	1	u(1)
if(more_rbsp_data()) {		
transform_8x8_mode_flag	1	u(1)
pic_scaling_matrix_present_flag	1	u(1)
if(pic_scaling_matrix_present_flag)		
for(i = 0; i < 6 + 2* transform_8x8_mode_flag; i++) {		
pic_scaling_list_present_flag[i]	1	u(1)
if(pic_scaling_list_present_flag[i])		
if(i < 6)		

scaling_list(ScalingList4x4[i], 16, UseDefaultScalingMatrix4x4Flag[i])	1	
else		
scaling_list(ScalingList8x8[i - 6], 64, UseDefaultScalingMatrix8x8Flag[i - 6])	1	
}		
second_chroma_qp_index_offset	1	se(v)
}		
rbsp_trailing_bits()	1	
}		

7.3.2.3 Supplemental enhancement information RBSP syntax

sei_rbsp() {	C	Descriptor
do		
sei_message()	5	
while(more_rbsp_data())		
rbsp_trailing_bits()	5	
}		

7.3.2.3.1 Supplemental enhancement information message syntax

sei_message() {	C	Descriptor
payloadType = 0		
while(next_bits(8) == 0xFF) {		
ff_byte /* equal to 0xFF */	5	f(8)
payloadType += 255		
}		
last_payload_type_byte	5	u(8)
payloadType += last_payload_type_byte		
payloadSize = 0		
while(next_bits(8) == 0xFF) {		
ff_byte /* equal to 0xFF */	5	f(8)
payloadSize += 255		
}		
last_payload_size_byte	5	u(8)
payloadSize += last_payload_size_byte		
sei_payload(payloadType, payloadSize)	5	
}		

7.3.2.4 Access unit delimiter RBSP syntax

access_unit_delimiter_rbsp() {	C	Descriptor
primary_pic_type	6	u(3)
rbsp_trailing_bits()	6	
}		

7.3.2.5 End of sequence RBSP syntax

end_of_seq_rbsp() {	C	Descriptor
}		

7.3.2.6 End of stream RBSP syntax

end_of_stream_rbsp() {	C	Descriptor
}		

7.3.2.7 Filler data RBSP syntax

filler_data_rbsp() {	C	Descriptor
while(next_bits(8) == 0xFF)		
ff_byte /* equal to 0xFF */	9	f(8)
rbsp_trailing_bits()	9	
}		

7.3.2.8 Slice layer without partitioning RBSP syntax

slice_layer_without_partitioning_rbsp() {	C	Descriptor
slice_header()	2	
slice_data() /* all categories of slice_data() syntax */	2 3 4	
rbsp_slice_trailing_bits()	2	
}		

7.3.2.9 Slice data partition RBSP syntax

7.3.2.9.1 Slice data partition A RBSP syntax

slice_data_partition_a_layer_rbsp() {	C	Descriptor
slice_header()	2	
slice_id	All	ue(v)
slice_data() /* only category 2 parts of slice_data() syntax */	2	
rbsp_slice_trailing_bits()	2	
}		

7.3.2.9.2 Slice data partition B RBSP syntax

	C	Descriptor
slice_data_partition_b_layer_rbsp() {		
slice_id	All	ue(v)
if(redundant_pic_cnt_present_flag)		
redundant_pic_cnt	All	ue(v)
slice_data() /* only category 3 parts of slice_data() syntax */	3	
rbsp_slice_trailing_bits()	3	
}		

7.3.2.9.3 Slice data partition C RBSP syntax

	C	Descriptor
slice_data_partition_c_layer_rbsp() {		
slice_id	All	ue(v)
if(redundant_pic_cnt_present_flag)		
redundant_pic_cnt	All	ue(v)
slice_data() /* only category 4 parts of slice_data() syntax */	4	
rbsp_slice_trailing_bits()	4	
}		

7.3.2.10 RBSP slice trailing bits syntax

	C	Descriptor
rbsp_slice_trailing_bits() {		
rbsp_trailing_bits()	All	
if(entropy_coding_mode_flag)		
while(more_rbsp_trailing_data())		
cabac_zero_word /* equal to 0x0000 */	All	f(16)
}		

7.3.2.11 RBSP trailing bits syntax

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

7.3.3 Slice header syntax

	C	Descriptor
slice_header() {		
first_mb_in_slice	2	ue(v)
slice_type	2	ue(v)
pic_parameter_set_id	2	ue(v)
frame_num	2	u(v)
if(!frame_mbs_only_flag) {		
field_pic_flag	2	u(1)
if(field_pic_flag)		
bottom_field_flag	2	u(1)
}		
if(nal_unit_type == 5)		
idr_pic_id	2	ue(v)
if(pic_order_cnt_type == 0) {		
pic_order_cnt_lsb	2	u(v)
if(pic_order_present_flag && !field_pic_flag)		
delta_pic_order_cnt_bottom	2	se(v)
}		
if(pic_order_cnt_type == 1 && !delta_pic_order_always_zero_flag) {		
delta_pic_order_cnt[0]	2	se(v)
if(pic_order_present_flag && !field_pic_flag)		
delta_pic_order_cnt[1]	2	se(v)
}		
if(redundant_pic_cnt_present_flag)		
redundant_pic_cnt	2	ue(v)
if(slice_type == B)		
direct_spatial_mv_pred_flag	2	u(1)
if(slice_type == P slice_type == SP slice_type == B) {		
num_ref_idx_active_override_flag	2	u(1)
if(num_ref_idx_active_override_flag) {		
num_ref_idx_l0_active_minus1	2	ue(v)
if(slice_type == B)		
num_ref_idx_l1_active_minus1	2	ue(v)
}		
}		
ref_pic_list_reordering()	2	
if((weighted_pred_flag && (slice_type == P slice_type == SP)) (weighted_bipred_idc == 1 && slice_type == B))		
pred_weight_table()	2	
if(nal_ref_idc != 0)		
dec_ref_pic_marking()	2	
if(entropy_coding_mode_flag && slice_type != I && slice_type != SI)		
cabac_init_idc	2	ue(v)
slice_qp_delta	2	se(v)
if(slice_type == SP slice_type == SI) {		
if(slice_type == SP)		
sp_for_switch_flag	2	u(1)

slice_qs_delta	2	se(v)
}		
if(deblocking_filter_control_present_flag) {		
disable_deblocking_filter_idc	2	ue(v)
if(disable_deblocking_filter_idc != 1) {		
slice_alpha_c0_offset_div2	2	se(v)
slice_beta_offset_div2	2	se(v)
}		
}		
if(num_slice_groups_minus1 > 0 && slice_group_map_type >= 3 && slice_group_map_type <= 5)		
slice_group_change_cycle	2	u(v)
}		

7.3.3.1 Reference picture list reordering syntax

	C	Descriptor
ref_pic_list_reordering() {		
if(slice_type != I && slice_type != SI) {		
ref_pic_list_reordering_flag_l0	2	u(1)
if(ref_pic_list_reordering_flag_l0)		
do {		
reordering_of_pic_nums_idc	2	ue(v)
if(reordering_of_pic_nums_idc == 0 reordering_of_pic_nums_idc == 1)		
abs_diff_pic_num_minus1	2	ue(v)
else if(reordering_of_pic_nums_idc == 2)		
long_term_pic_num	2	ue(v)
} while(reordering_of_pic_nums_idc != 3)		
}		
if(slice_type == B) {		
ref_pic_list_reordering_flag_l1	2	u(1)
if(ref_pic_list_reordering_flag_l1)		
do {		
reordering_of_pic_nums_idc	2	ue(v)
if(reordering_of_pic_nums_idc == 0 reordering_of_pic_nums_idc == 1)		
abs_diff_pic_num_minus1	2	ue(v)
else if(reordering_of_pic_nums_idc == 2)		
long_term_pic_num	2	ue(v)
} while(reordering_of_pic_nums_idc != 3)		
}		
}		

7.3.3.2 Prediction weight table syntax

	C	Descriptor
pred_weight_table() {		
luma_log2_weight_denom	2	ue(v)
if(chroma_format_idc != 0)		
chroma_log2_weight_denom	2	ue(v)
for(i = 0; i <= num_ref_idx_l0_active_minus1; i++) {		
luma_weight_l0_flag	2	u(1)
if(luma_weight_l0_flag) {		
luma_weight_l0[i]	2	se(v)
luma_offset_l0[i]	2	se(v)
}		
if (chroma_format_idc != 0) {		
chroma_weight_l0_flag	2	u(1)
if(chroma_weight_l0_flag)		
for(j = 0; j < 2; j++) {		
chroma_weight_l0[i][j]	2	se(v)
chroma_offset_l0[i][j]	2	se(v)
}		
}		
}		
if(slice_type == B)		
for(i = 0; i <= num_ref_idx_l1_active_minus1; i++) {		
luma_weight_l1_flag	2	u(1)
if(luma_weight_l1_flag) {		
luma_weight_l1[i]	2	se(v)
luma_offset_l1[i]	2	se(v)
}		
if(chroma_format_idc != 0) {		
chroma_weight_l1_flag	2	u(1)
if(chroma_weight_l1_flag)		
for(j = 0; j < 2; j++) {		
chroma_weight_l1[i][j]	2	se(v)
chroma_offset_l1[i][j]	2	se(v)
}		
}		
}		
}		

7.3.3.3 Decoded reference picture marking syntax

	C	Descriptor
dec_ref_pic_marking() {		
if(nal_unit_type == 5) {		
no_output_of_prior_pics_flag	2 5	u(1)
long_term_reference_flag	2 5	u(1)
} else {		
adaptive_ref_pic_marking_mode_flag	2 5	u(1)
if(adaptive_ref_pic_marking_mode_flag)		
do {		
memory_management_control_operation	2 5	ue(v)
if(memory_management_control_operation == 1 memory_management_control_operation == 3)		
difference_of_pic_nums_minus1	2 5	ue(v)
if(memory_management_control_operation == 2)		
long_term_pic_num	2 5	ue(v)
if(memory_management_control_operation == 3 memory_management_control_operation == 6)		
long_term_frame_idx	2 5	ue(v)
if(memory_management_control_operation == 4)		
max_long_term_frame_idx_plus1	2 5	ue(v)
} while(memory_management_control_operation != 0)		
}		
}		

7.3.4 Slice data syntax

	C	Descriptor
slice_data() {		
if(entropy_coding_mode_flag)		
while(!byte_aligned())		
cabac_alignment_one_bit	2	f(1)
CurrMbAddr = first_mb_in_slice * (1 + MbaffFrameFlag)		
moreDataFlag = 1		
prevMbSkipped = 0		
do {		
if(slice_type != I && slice_type != SI)		
if(!entropy_coding_mode_flag) {		
mb_skip_run	2	ue(v)
prevMbSkipped = (mb_skip_run > 0)		
for(i=0; i<mb_skip_run; i++)		
CurrMbAddr = NextMbAddress(CurrMbAddr)		
moreDataFlag = more_rbsp_data()		
} else {		
mb_skip_flag	2	ae(v)
moreDataFlag = !mb_skip_flag		
}		
if(moreDataFlag) {		
if(MbaffFrameFlag && (CurrMbAddr % 2 == 0 (CurrMbAddr % 2 == 1 && prevMbSkipped)))		
mb_field_decoding_flag	2	u(1) ae(v)
macroblock_layer()	2 3 4	
}		
if(!entropy_coding_mode_flag)		
moreDataFlag = more_rbsp_data()		
else {		
if(slice_type != I && slice_type != SI)		
prevMbSkipped = mb_skip_flag		
if(MbaffFrameFlag && CurrMbAddr % 2 == 0)		
moreDataFlag = 1		
else {		
end_of_slice_flag	2	ae(v)
moreDataFlag = !end_of_slice_flag		
}		
}		
CurrMbAddr = NextMbAddress(CurrMbAddr)		
} while(moreDataFlag)		
}		

7.3.5 Macroblock layer syntax

	C	Descriptor
macroblock_layer() {		
mb_type	2	ue(v) ae(v)
if(mb_type == I_PCM) {		
while(!byte_aligned())		
pcm_alignment_zero_bit	2	f(1)
for(i = 0; i < 256; i++)		
pcm_sample_luma[i]	2	u(v)
for(i = 0; i < 2 * MbWidthC * MbHeightC; i++)		
pcm_sample_chroma[i]	2	u(v)
} else {		
noSubMbPartSizeLessThan8x8Flag = 1		
if(mb_type != I_NxN && MbPartPredMode(mb_type, 0) != Intra_16x16 && NumMbPart(mb_type) == 4) {		
sub_mb_pred(mb_type)	2	
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
if(sub_mb_type[mbPartIdx] != B_Direct_8x8) {		
if(NumSubMbPart(sub_mb_type[mbPartIdx]) > 1)		
noSubMbPartSizeLessThan8x8Flag = 0		
} else if(!direct_8x8_inference_flag)		
noSubMbPartSizeLessThan8x8Flag = 0		
} else {		
if(transform_8x8_mode_flag && mb_type == I_NxN)		
transform_size_8x8_flag	2	u(1) ae(v)
mb_pred(mb_type)	2	
}		
if(MbPartPredMode(mb_type, 0) != Intra_16x16) {		
coded_block_pattern	2	me(v) ae(v)
if(CodedBlockPatternLuma > 0 && transform_8x8_mode_flag && mb_type != I_NxN && noSubMbPartSizeLessThan8x8Flag && (mb_type != B_Direct_16x16 direct_8x8_inference_flag))		
transform_size_8x8_flag	2	u(1) ae(v)
}		
if(CodedBlockPatternLuma > 0 CodedBlockPatternChroma > 0 MbPartPredMode(mb_type, 0) == Intra_16x16) {		
mb_qp_delta	2	se(v) ae(v)
residual()	3 4	
}		
}		
}		
}		

7.3.5.1 Macroblock prediction syntax

	C	Descriptor
mb_pred(mb_type) {		
if(MbPartPredMode(mb_type, 0) == Intra_4x4 MbPartPredMode(mb_type, 0) == Intra_8x8 MbPartPredMode(mb_type, 0) == Intra_16x16) {		
if(MbPartPredMode(mb_type, 0) == Intra_4x4)		
for(luma4x4BlkIdx=0; luma4x4BlkIdx<16; luma4x4BlkIdx++) {		
prev_intra4x4_pred_mode_flag [luma4x4BlkIdx]	2	u(1) ae(v)
if(!prev_intra4x4_pred_mode_flag[luma4x4BlkIdx])		
rem_intra4x4_pred_mode [luma4x4BlkIdx]	2	u(3) ae(v)
}		
if(MbPartPredMode(mb_type, 0) == Intra_8x8)		
for(luma8x8BlkIdx=0; luma8x8BlkIdx<4; luma8x8BlkIdx++) {		
prev_intra8x8_pred_mode_flag [luma8x8BlkIdx]	2	u(1) ae(v)
if(!prev_intra8x8_pred_mode_flag[luma8x8BlkIdx])		
rem_intra8x8_pred_mode [luma8x8BlkIdx]	2	u(3) ae(v)
}		
if(chroma_format_idc != 0)		
intra_chroma_pred_mode	2	ue(v) ae(v)
} else if(MbPartPredMode(mb_type, 0) != Direct) {		
for(mbPartIdx = 0; mbPartIdx < NumMbPart(mb_type); mbPartIdx++)		
if((num_ref_idx_l0_active_minus1 > 0 mb_field_decoding_flag) && MbPartPredMode(mb_type, mbPartIdx) != Pred_L1)		
ref_idx_l0 [mbPartIdx]	2	te(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < NumMbPart(mb_type); mbPartIdx++)		
if((num_ref_idx_l1_active_minus1 > 0 mb_field_decoding_flag) && MbPartPredMode(mb_type, mbPartIdx) != Pred_L0)		
ref_idx_l1 [mbPartIdx]	2	te(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < NumMbPart(mb_type); mbPartIdx++)		
if(MbPartPredMode(mb_type, mbPartIdx) != Pred_L1)		
for(compIdx = 0; compIdx < 2; compIdx++)		
mvd_l0 [mbPartIdx][0][compIdx]	2	se(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < NumMbPart(mb_type); mbPartIdx++)		
if(MbPartPredMode(mb_type, mbPartIdx) != Pred_L0)		
for(compIdx = 0; compIdx < 2; compIdx++)		
mvd_l1 [mbPartIdx][0][compIdx]	2	se(v) ae(v)
}		
}		

7.3.5.2 Sub-macroblock prediction syntax

	C	Descriptor
sub mb_pred(mb_type) {		
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
sub mb_type [mbPartIdx]	2	ue(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
if((num_ref_idx_l0_active_minus1 > 0 mb_field_decoding_flag) && mb_type != P_8x8ref0 && sub_mb_type[mbPartIdx] != B_Direct_8x8 && SubMbPredMode(sub_mb_type[mbPartIdx]) != Pred_L1)		
ref_idx_l0 [mbPartIdx]	2	te(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
if((num_ref_idx_l1_active_minus1 > 0 mb_field_decoding_flag) && sub_mb_type[mbPartIdx] != B_Direct_8x8 && SubMbPredMode(sub_mb_type[mbPartIdx]) != Pred_L0)		
ref_idx_l1 [mbPartIdx]	2	te(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
if(sub_mb_type[mbPartIdx] != B_Direct_8x8 && SubMbPredMode(sub_mb_type[mbPartIdx]) != Pred_L1)		
for(subMbPartIdx = 0; subMbPartIdx < NumSubMbPart(sub_mb_type[mbPartIdx]); subMbPartIdx++)		
for(compIdx = 0; compIdx < 2; compIdx++)		
mvd_l0 [mbPartIdx][subMbPartIdx][compIdx]	2	se(v) ae(v)
for(mbPartIdx = 0; mbPartIdx < 4; mbPartIdx++)		
if(sub_mb_type[mbPartIdx] != B_Direct_8x8 && SubMbPredMode(sub_mb_type[mbPartIdx]) != Pred_L0)		
for(subMbPartIdx = 0; subMbPartIdx < NumSubMbPart(sub_mb_type[mbPartIdx]); subMbPartIdx++)		
for(compIdx = 0; compIdx < 2; compIdx++)		
mvd_l1 [mbPartIdx][subMbPartIdx][compIdx]	2	se(v) ae(v)
}		

7.3.5.3 Residual data syntax

residual() {	C	Descriptor
if(!entropy_coding_mode_flag)		
residual_block = residual_block_cavlc		
else		
residual_block = residual_block_cabac		
if(MbPartPredMode(mb_type, 0) == Intra_16x16)		
residual_block(Intra16x16DCLevel, 16)	3	
for(i8x8 = 0; i8x8 < 4; i8x8++) /* each luma 8x8 block */		
if(!transform_size_8x8_flag !entropy_coding_mode_flag)		
for(i4x4 = 0; i4x4 < 4; i4x4++) { /* each 4x4 sub-block of block */		
if(CodedBlockPatternLuma & (1 << i8x8))		
if(MbPartPredMode(mb_type, 0) == Intra_16x16)		
residual_block(Intra16x16ACLevel[i8x8 * 4 + i4x4], 15)	3	
else		
residual_block(LumaLevel[i8x8 * 4 + i4x4], 16)	3 4	
else if(MbPartPredMode(mb_type, 0) == Intra_16x16)		
for(i = 0; i < 15; i++)		
Intra16x16ACLevel[i8x8 * 4 + i4x4][i] = 0		
else		
for(i = 0; i < 16; i++)		
LumaLevel[i8x8 * 4 + i4x4][i] = 0		
if(!entropy_coding_mode_flag && transform_size_8x8_flag)		
for(i = 0; i < 16; i++)		
LumaLevel8x8[i8x8][4 * i + i4x4] =		
LumaLevel[i8x8 * 4 + i4x4][i]		
}		
else if(CodedBlockPatternLuma & (1 << i8x8))		
residual_block(LumaLevel8x8[i8x8], 64)	3 4	
else		
for(i = 0; i < 64; i++)		
LumaLevel8x8[i8x8][i] = 0		
if(chroma_format_idc != 0) {		
NumC8x8 = 4 / (SubWidthC * SubHeightC)		
for(iCbCr = 0; iCbCr < 2; iCbCr++)		
if(CodedBlockPatternChroma & 3) /* chroma DC residual present */		
residual_block(ChromaDCLevel[iCbCr], 4 * NumC8x8)	3 4	
else		
for(i = 0; i < 4 * NumC8x8; i++)		
ChromaDCLevel[iCbCr][i] = 0		
for(iCbCr = 0; iCbCr < 2; iCbCr++)		
for(i8x8 = 0; i8x8 < NumC8x8; i8x8++)		
for(i4x4 = 0; i4x4 < 4; i4x4++)		
if(CodedBlockPatternChroma & 2)		
/* chroma AC residual present */		
residual_block(ChromaACLevel[iCbCr][i8x8*4+i4x4], 15)	3 4	
else		
for(i = 0; i < 15; i++)		
ChromaACLevel[iCbCr][i8x8*4+i4x4][i] = 0		
}		

7.3.5.3.1 Residual block CAVLC syntax

	C	Descriptor
residual_block_cavlc(coeffLevel, maxNumCoeff) {		
for(i = 0; i < maxNumCoeff; i++)		
coeffLevel[i] = 0		
coeff_token	3 4	ce(v)
if(TotalCoeff(coeff_token) > 0) {		
if(TotalCoeff(coeff_token) > 10 && TrailingOnes(coeff_token) < 3)		
suffixLength = 1		
else		
suffixLength = 0		
for(i = 0; i < TotalCoeff(coeff_token); i++)		
if(i < TrailingOnes(coeff_token)) {		
trailing_ones_sign_flag	3 4	u(1)
level[i] = 1 - 2 * trailing_ones_sign_flag		
} else {		
level_prefix	3 4	ce(v)
levelCode = (Min(15, level_prefix) << suffixLength)		
if(suffixLength > 0 level_prefix >= 14) {		
level_suffix	3 4	u(v)
levelCode += level_suffix		
}		
if(level_prefix >= 15 && suffixLength == 0)		
levelCode += 15		
if(level_prefix >= 16)		
levelCode += (1 << (level_prefix - 3)) - 4096		
if(i == TrailingOnes(coeff_token) &&		
TrailingOnes(coeff_token) < 3)		
levelCode += 2		
if(levelCode % 2 == 0)		
level[i] = (levelCode + 2) >> 1		
else		
level[i] = (-levelCode - 1) >> 1		
if(suffixLength == 0)		
suffixLength = 1		
if(Abs(level[i]) > (3 << (suffixLength - 1)) &&		
suffixLength < 6)		
suffixLength++		
}		
if(TotalCoeff(coeff_token) < maxNumCoeff) {		
total_zeros	3 4	ce(v)
zerosLeft = total_zeros		
} else		
zerosLeft = 0		
for(i = 0; i < TotalCoeff(coeff_token) - 1; i++) {		
if(zerosLeft > 0) {		
run_before	3 4	ce(v)
run[i] = run_before		
} else		
run[i] = 0		

zerosLeft = zerosLeft - run[i]		
}		
run[TotalCoeff(coeff_token) - 1] = zerosLeft		
coeffNum = -1		
for(i = TotalCoeff(coeff_token) - 1; i >= 0; i--) {		
coeffNum += run[i] + 1		
coeffLevel[coeffNum] = level[i]		
}		
}		
}		

7.3.5.3.2 Residual block CABAC syntax

	C	Descriptor
residual_block_cabac(coeffLevel, maxNumCoeff) {		
if(maxNumCoeff == 64)		
coded_block_flag = 1		
else		
coded_block_flag	3 4	ae(v)
if(coded_block_flag) {		
numCoeff = maxNumCoeff		
i = 0		
do {		
significant_coeff_flag[i]	3 4	ae(v)
if(significant_coeff_flag[i]) {		
last_significant_coeff_flag[i]	3 4	ae(v)
if(last_significant_coeff_flag[i]) {		
numCoeff = i + 1		
for(j = numCoeff; j < maxNumCoeff; j++)		
coeffLevel[j] = 0		
}		
}		
i++		
} while(i < numCoeff - 1)		
coeff_abs_level_minus1[numCoeff - 1]	3 4	ae(v)
coeff_sign_flag[numCoeff - 1]	3 4	ae(v)
coeffLevel[numCoeff - 1] =		
(coeff_abs_level_minus1[numCoeff - 1] + 1) *		
(1 - 2 * coeff_sign_flag[numCoeff - 1])		
for(i = numCoeff - 2; i >= 0; i--)		
if(significant_coeff_flag[i]) {		
coeff_abs_level_minus1[i]	3 4	ae(v)
coeff_sign_flag[i]	3 4	ae(v)
coeffLevel[i] = (coeff_abs_level_minus1[i] + 1) *		
(1 - 2 * coeff_sign_flag[i])		
} else		
coeffLevel[i] = 0		
} else		
for(i = 0; i < maxNumCoeff; i++)		
coeffLevel[i] = 0		
}		

7.4 Semantics

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 Recommendation | International Standard.

7.4.1 NAL unit semantics

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.

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 Recommendation | International Standard.

forbidden_zero_bit shall be equal to 0.

nal_ref_idc not equal to 0 specifies that the content of the NAL unit contains a sequence parameter set or a picture parameter set or a slice of a reference picture or a slice data partition of a reference picture.

nal_ref_idc equal to 0 for a NAL unit containing a slice or slice data partition indicates that the slice or slice data partition is part of a non-reference picture.

nal_ref_idc shall not be equal to 0 for sequence parameter set or sequence parameter set extension or picture parameter set NAL units. When nal_ref_idc is equal to 0 for one slice or slice data partition NAL unit of a particular picture, it shall be equal to 0 for all slice and slice data partition NAL units of the picture.

nal_ref_idc shall not be equal to 0 for IDR NAL units, i.e., NAL units with nal_unit_type equal to 5.

nal_ref_idc shall be equal to 0 for all NAL units having nal_unit_type equal to 6, 9, 10, 11, or 12.

nal_unit_type specifies the type of RBSP data structure contained in the NAL unit as specified in Table 7-1. VCL NAL units are specified as those NAL units having nal_unit_type equal to 1 to 5, inclusive. All remaining NAL units are called non-VCL NAL units.

The column marked "C" in Table 7-1 lists the categories of the syntax elements that may be present in the NAL unit. In addition, syntax elements with syntax category "All" may be present, as determined by the syntax and semantics of the RBSP data structure. The presence or absence of any syntax elements of a particular listed category is determined from the syntax and semantics of the associated RBSP data structure. nal_unit_type shall not be equal to 3 or 4 unless at least one syntax element is present in the RBSP data structure having a syntax element category value equal to the value of nal_unit_type and not categorized as "All".

Table 7-1 – NAL unit type codes

nal_unit_type	Content of NAL unit and RBSP syntax structure	C
0	Unspecified	
1	Coded slice of a non-IDR picture slice_layer_without_partitioning_rbsp()	2, 3, 4
2	Coded slice data partition A slice_data_partition_a_layer_rbsp()	2
3	Coded slice data partition B slice_data_partition_b_layer_rbsp()	3
4	Coded slice data partition C slice_data_partition_c_layer_rbsp()	4
5	Coded slice of an IDR picture slice_layer_without_partitioning_rbsp()	2, 3
6	Supplemental enhancement information (SEI) sei_rbsp()	5
7	Sequence parameter set seq_parameter_set_rbsp()	0
8	Picture parameter set pic_parameter_set_rbsp()	1
9	Access unit delimiter access_unit_delimiter_rbsp()	6
10	End of sequence end_of_seq_rbsp()	7
11	End of stream end_of_stream_rbsp()	8
12	Filler data filler_data_rbsp()	9
13	Sequence parameter set extension seq_parameter_set_extension_rbsp()	10
14..18	Reserved	
19	Coded slice of an auxiliary coded picture without partitioning slice_layer_without_partitioning_rbsp()	2, 3, 4
20..23	Reserved	
24..31	Unspecified	

NAL units having nal_unit_type equal to 13 and 19 may be discarded by decoders without affecting the decoding process for NAL units having nal_unit_type not equal to 13 or 19 and without affecting conformance to this Recommendation | International Standard.

NAL units that use nal_unit_type equal to 0 or in the range of 24..31, inclusive, shall not affect the decoding process specified in this Recommendation | International Standard.

NOTE 2 – NAL unit types 0 and 24..31 may be used as determined by the application. No decoding process for these values of nal_unit_type is specified in this Recommendation | International Standard.

Decoders shall ignore (remove from the bitstream and discard) the contents of all NAL units that use reserved values of nal_unit_type.

NOTE 3 – This requirement allows future definition of compatible extensions to this Recommendation | International Standard.

In the text, coded slice NAL unit collectively refers to a coded slice of a non-IDR picture NAL unit or to a coded slice of an IDR picture NAL unit.

When the value of `nal_unit_type` is equal to 5 for a NAL unit containing a slice of a coded picture, the value of `nal_unit_type` shall be 5 in all other VCL NAL units of the same coded picture. Such a picture is referred to as an IDR picture.

NOTE 4 – Slice data partitioning cannot be used for IDR pictures.

`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 shall contain 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, and
 - 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 shall be 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 shall be as specified in Table 7-1.

NOTE 5 – 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

NOTE 6 – When `nal_unit_type` is equal to 0, particular care must be exercised in the design of encoders to avoid the presence of the above-listed three-byte and four-byte patterns at the beginning of the NAL unit syntax structure, as the syntax element `emulation_prevention_three_byte` cannot be the third byte of a NAL unit.

7.4.1.1 Encapsulation of an SODB within an RBSP (informative)

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

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 specified 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, and

- to enable a NAL unit to have a size larger than that of the SODB under some circumstances (using one or more `cabac_zero_word`).

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

The RBSP data is searched for byte-aligned bits of the following binary patterns:

'00000000 00000000 000000xx' (where xx represents any 2 bit pattern: 00, 01, 10, or 11),

and a byte equal to 0x03 is inserted to replace these bit patterns with the patterns

'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 resulting sequence of bytes is then prefixed with the first byte of the NAL unit containing the indication of the type of RBSP data structure it contains. This results in the construction of the entire NAL unit.

This process can allow any SODB to be represented in a NAL unit while ensuring that

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

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

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.1, and E.1 specifies the decoding order of syntax elements. Decoders conforming to this Recommendation | International Standard shall be capable of receiving NAL units and their syntax elements in decoding order.

7.4.1.2.1 Order of sequence and picture parameter set RBSPs and their activation

NOTE 1 – The sequence and picture parameter set mechanism decouples the transmission of infrequently changing information from the transmission of coded macroblock data. Sequence and picture parameter sets may, in some applications, be conveyed "out-of-band" using a reliable transport mechanism.

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

When a picture parameter set RBSP (with a particular value of `pic_parameter_set_id`) is not active and it is referred to by a coded slice NAL unit or coded slice data partition A NAL unit (using that value of `pic_parameter_set_id`), it is activated. This picture parameter set RBSP is called the active picture parameter set RBSP until it is deactivated by the activation of another picture parameter set RBSP. A picture parameter set RBSP, with that particular value of `pic_parameter_set_id`, shall be available to the decoding process prior to its activation.

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

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

When a sequence parameter set RBSP (with a particular value of `seq_parameter_set_id`) is not already active and it is referred to by activation of a picture parameter set RBSP (using that value of `seq_parameter_set_id`) or is referred to by an SEI NAL unit containing a buffering period SEI message (using that value of `seq_parameter_set_id`), it is activated. This sequence parameter set RBSP is called the active sequence parameter set RBSP until it is deactivated by the activation of another sequence parameter set RBSP. A sequence parameter set RBSP, with that particular value of `seq_parameter_set_id`, shall be available to the decoding process prior to its activation. An activated sequence parameter set RBSP shall remain active for the entire coded video sequence.

NOTE 2 – Because an IDR access unit begins a new coded video sequence and an activated sequence parameter set RBSP must remain active for the entire coded video sequence, a sequence parameter set RBSP can only be activated by a buffering period SEI message when the buffering period SEI message is part of an IDR access unit.

Any sequence parameter set NAL unit containing the value of `seq_parameter_set_id` for the active sequence parameter set RBSP shall have the same content as that of the active sequence parameter set RBSP unless it follows the last access unit of a coded video sequence and precedes the first VCL NAL unit and the first SEI NAL unit containing a buffering period SEI message (when present) of another coded video sequence.

NOTE 3 – If picture parameter set RBSP or sequence parameter set RBSP are conveyed within the bitstream, these constraints impose an order constraint on the NAL units that contain the picture parameter set RBSP or sequence parameter set RBSP, respectively. Otherwise (picture parameter set RBSP or sequence parameter set RBSP are conveyed by other means not specified in this Recommendation | International Standard), they must be available to the decoding process in a timely fashion such that these constraints are obeyed.

When present, a sequence parameter set extension RBSP includes parameters having a similar function to those of a sequence parameter set RBSP. For purposes of establishing constraints on the syntax elements of the sequence parameter set extension RBSP and for purposes of determining activation of a sequence parameter set extension RBSP, the sequence parameter set extension RBSP shall be considered part of the preceding sequence parameter set RBSP with the same value of `seq_parameter_set_id`. When a sequence parameter set RBSP is present that is not followed by a sequence parameter set extension RBSP with the same value of `seq_parameter_set_id` prior to the activation of the sequence parameter set RBSP, the sequence parameter set extension RBSP and its syntax elements shall be considered not present for the active sequence parameter set RBSP.

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 sequence parameter sets and picture parameter sets and other syntax elements are expressions of constraints that apply only to the active sequence parameter set and the active picture parameter set. If any sequence parameter set RBSP is present that is not activated in the bitstream, its syntax elements shall have values that would conform to the specified constraints if it were activated by reference in an otherwise-conforming bitstream. If any picture parameter set RBSP is present that is not ever activated in the bitstream, its syntax elements shall have values that would conform to the specified constraints if it were activated by reference in an otherwise-conforming bitstream.

During operation of the decoding process (see clause 8), the values of parameters of the active picture parameter set and the active sequence parameter set shall be considered in effect. For interpretation of SEI messages, the values of the parameters of the picture parameter set and sequence parameter set that are active for the operation of the decoding process for the VCL NAL units of the primary coded picture in the same access unit shall be considered in effect unless otherwise specified in the SEI message semantics.

7.4.1.2.2 Order of access units and association to coded video sequences

A bitstream conforming to this Recommendation | International Standard consists of one or more coded video sequences.

A coded video sequence 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 7.4.1.2.3.

The first access unit of each coded video sequence is an IDR access unit. All subsequent access units in the coded video sequence are non-IDR access units.

The values of picture order count for the coded pictures in consecutive access units in decoding order containing non-reference pictures shall be non-decreasing.

When present, an access unit following an access unit that contains an end of sequence NAL unit shall be an IDR access unit.

When an SEI NAL unit contains data that pertain to more than one access unit (for example, when the SEI NAL unit has a coded video sequence as its scope), it shall be contained in the first access unit to which it applies.

When an end of stream NAL unit is present in an access unit, this access unit shall be the last access unit in the bitstream and the end of stream NAL unit shall be the last NAL unit in that access unit.

7.4.1.2.3 Order of NAL units and coded pictures and association to access units

An access unit consists of one primary coded picture, zero or more corresponding redundant coded pictures, and zero or more non-VCL NAL units. The association of VCL NAL units to primary or redundant coded pictures is described in subclause 7.4.1.2.5.

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 primary coded picture specifies the start of a new access unit.

- access unit delimiter NAL unit (when present)
- sequence parameter set NAL unit (when present)
- picture parameter set NAL unit (when present)
- SEI NAL unit (when present)
- NAL units with `nal_unit_type` in the range of 14 to 18, inclusive
- first VCL NAL unit of a primary coded picture (always present)

The constraints for the detection of the first VCL NAL unit of a primary coded picture are specified in subclause 7.4.1.2.4.

The following constraints shall be obeyed by the order of the coded pictures and non-VCL NAL units within an access unit.

- 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 SEI NAL units are present, they shall precede the primary coded picture.
- When an SEI NAL unit containing a buffering period SEI message is present, the buffering period SEI message shall be the first SEI message payload of the first SEI NAL unit in the access unit
- The primary coded picture shall precede the corresponding redundant coded pictures.
- When redundant coded pictures are present, they shall be ordered in ascending order of the value of `redundant_pic_cnt`.
- When a sequence parameter set extension NAL unit is present, it shall be the next NAL unit after a sequence parameter set NAL unit having the same value of `seq_parameter_set_id` as in the sequence parameter set extension NAL unit.
- When one or more coded slice of an auxiliary coded picture without partitioning NAL units is present, they shall follow the primary coded picture and all redundant coded pictures (if any).
- When an end of sequence NAL unit is present, it shall follow the primary coded picture and all redundant coded pictures (if any) and all coded slice of an auxiliary coded picture without partitioning NAL units (if any).
- When an end of stream NAL unit is present, it shall be the last NAL unit.
- NAL units having `nal_unit_type` equal to 0, 12, or in the range of 20 to 31, inclusive, shall not precede the first VCL NAL unit of the primary coded picture.

NOTE 1 – Sequence parameter set NAL units or picture parameter set NAL units may be present in an access unit, but cannot follow the last VCL NAL unit of the primary coded picture within the access unit, as this condition would specify the start of a new access unit.

NOTE 2 – When a NAL unit having `nal_unit_type` equal to 7 or 8 is present in an access unit, it may or may not be referred to in the coded pictures of the access unit in which it is present, and may be referred to in coded pictures of subsequent access units.

The structure of access units not containing any NAL units with `nal_unit_type` equal to 0, 7, 8, or in the range of 12 to 18, inclusive, or in the range of 20 to 31, inclusive, is shown in Figure 7-1.

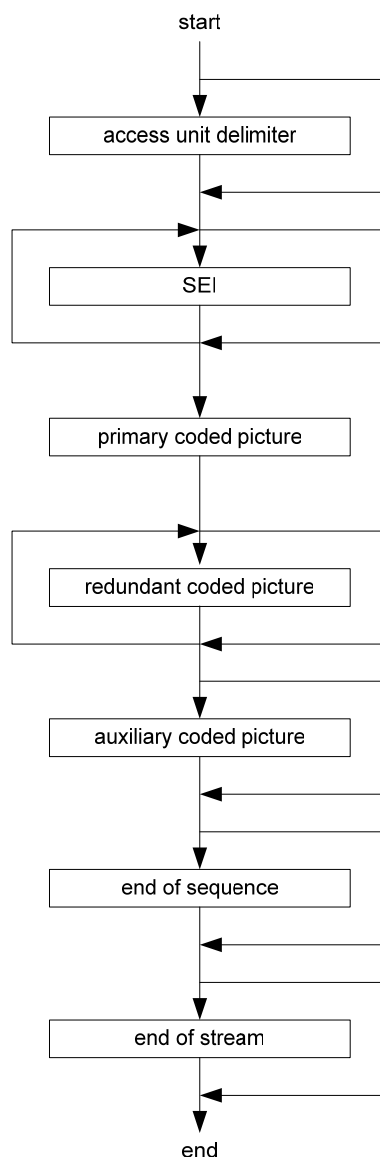


Figure 7-1 – Structure of an access unit not containing any NAL units with nal_unit_type equal to 0, 7, 8, or in the range of 12 to 18, inclusive, or in the range of 20 to 31, inclusive

7.4.1.2.4 Detection of the first VCL NAL unit of a primary coded picture

This subclause specifies constraints on VCL NAL unit syntax that are sufficient to enable the detection of the first VCL NAL unit of each primary coded picture.

Any coded slice NAL unit or coded slice data partition A NAL unit of the primary coded picture of the current access unit shall be different from any coded slice NAL unit or coded slice data partition A NAL unit of the primary coded picture of the previous access unit in one or more of the following ways.

- frame_num differs in value. The value of frame_num used to test this condition is the value of frame_num that appears in the syntax of the slice header, regardless of whether that value is inferred to have been equal to 0 for subsequent use in the decoding process due to the presence of memory_management_control_operation equal to 5.

NOTE 1 – A consequence of the above statement is that a primary coded picture having frame_num equal to 1 cannot contain a memory_management_control_operation equal to 5 unless some other condition listed below is fulfilled for the next primary coded picture that follows after it (if any).

- pic_parameter_set_id differs in value.
- field_pic_flag differs in value.

- `bottom_field_flag` is present in both and differs in value.
- `nal_ref_idc` differs in value with one of the `nal_ref_idc` values being equal to 0.
- `pic_order_cnt_type` is equal to 0 for both and either `pic_order_cnt_lsb` differs in value, or `delta_pic_order_cnt_bottom` differs in value.
- `pic_order_cnt_type` is equal to 1 for both and either `delta_pic_order_cnt[0]` differs in value, or `delta_pic_order_cnt[1]` differs in value.
- `nal_unit_type` differs in value with one of the `nal_unit_type` values being equal to 5.
- `nal_unit_type` is equal to 5 for both and `idr_pic_id` differs in value.

NOTE 2 – Some of the VCL NAL units in redundant coded pictures or some non-VCL NAL units (e.g. an access unit delimiter NAL unit) may also be used for the detection of the boundary between access units, and may therefore aid in the detection of the start of a new primary coded picture.

7.4.1.2.5 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 IDR picture is constrained as follows.

- If arbitrary slice order is allowed as specified in Annex A, coded slice of an IDR picture NAL units may have any order relative to each other.
- Otherwise (arbitrary slice order is not allowed), the order of coded slice of an IDR picture NAL units shall be in the order of increasing macroblock address for the first macroblock of each coded slice of an IDR picture NAL unit.

The order of the VCL NAL units within a coded non-IDR picture is constrained as follows.

- If arbitrary slice order is allowed as specified in Annex A, coded slice of a non-IDR picture NAL units or coded slice data partition A NAL units may have any order relative to each other. A coded slice data partition A NAL unit with a particular value of `slice_id` shall precede any present coded slice data partition B NAL unit with the same value of `slice_id`. A coded slice data partition A NAL unit with a particular value of `slice_id` shall precede any present coded slice data partition C NAL unit with the same value of `slice_id`. When a coded slice data partition B NAL unit with a particular value of `slice_id` is present, it shall precede any present coded slice data partition C NAL unit with the same value of `slice_id`.
- Otherwise (arbitrary slice order is not allowed), the order of coded slice of a non-IDR picture NAL units or coded slice data partition A NAL units shall be in the order of increasing macroblock address for the first macroblock of each coded slice of a non-IDR picture NAL unit or coded slice data partition A NAL unit. A coded slice data partition A NAL unit with a particular value of `slice_id` shall immediately precede any present coded slice data partition B NAL unit with the same value of `slice_id`. A coded slice data partition A NAL unit with a particular value of `slice_id` shall immediately precede any present coded slice data partition C NAL unit with the same value of `slice_id`, when a coded slice data partition B NAL unit with the same value of `slice_id` is not present. When a coded slice data partition B NAL unit with a particular value of `slice_id` is present, it shall immediately precede any present coded slice data partition C NAL unit with the same value of `slice_id`.

NAL units having `nal_unit_type` equal to 12 may be present in the access unit but shall not precede the first VCL NAL unit of the primary coded picture within the access unit.

NAL units having `nal_unit_type` equal to 0 or in the range of 24 to 31, inclusive, which are unspecified, may be present in the access unit but shall not precede the first VCL NAL unit of the primary coded picture within the access unit.

NAL units having `nal_unit_type` in the range of 20 to 23, inclusive, which are reserved, shall not precede the first VCL NAL unit of the primary coded picture within the access unit (when specified in the future by ITU-T | ISO/IEC).

7.4.2 Raw byte sequence payloads and RBSP trailing bits semantics

7.4.2.1 Sequence parameter set RBSP semantics

`profile_idc` and `level_idc` indicate the profile and level to which the bitstream conforms, as specified in Annex A.

`constraint_set0_flag` equal to 1 indicates that the bitstream obeys all constraints specified in subclause A.2.1. `constraint_set0_flag` equal to 0 indicates that the bitstream may or may not obey all constraints specified in subclause A.2.1.

constraint_set1_flag equal to 1 indicates that the bitstream obeys all constraints specified in subclause A.2.2. **constraint_set1_flag** equal to 0 indicates that the bitstream may or may not obey all constraints specified in subclause A.2.2.

constraint_set2_flag equal to 1 indicates that the bitstream obeys all constraints specified in subclause A.2.3. **constraint_set2_flag** equal to 0 indicates that the bitstream may or may not obey all constraints specified in subclause A.2.3.

NOTE 1 – When one or more than one of **constraint_set0_flag**, **constraint_set1_flag**, or **constraint_set2_flag** are equal to 1, the bitstream must obey the constraints of all of the indicated subclauses of subclause A.2. When **profile_idc** is equal to 100, 110, 122, or 144, the values of **constraint_set0_flag**, **constraint_set1_flag**, and **constraint_set2_flag** must all be equal to 0.

constraint_set3_flag indicates the following.

- If **profile_idc** is equal to 66, 77, or 88 and **level_idc** is equal to 11, **constraint_set3_flag** equal to 1 indicates that the bitstream obeys all constraints specified in Annex A for level 1b and **constraint_set3_flag** equal to 0 indicates that the bitstream may or may not obey all constraints specified in Annex A for level 1b.
- Otherwise (**profile_idc** is equal to 100, 110, 122, or 144 or **level_idc** is not equal to 11), the value of 1 for **constraint_set3_flag** is reserved for future use by ITU-T | ISO/IEC. **constraint_set3_flag** shall be equal to 0 in bitstreams conforming to this Recommendation | International Standard when **profile_idc** is equal to 100, 110, 122, or 144 or **level_idc** is not equal to 11. Decoders conforming to this Recommendation | International Standard shall ignore the value of **constraint_set3_flag** when **profile_idc** is equal to 100, 110, 122, or 144 or **level_idc** is not equal to 11.

reserved_zero_4bits shall be equal to 0. Other values of **reserved_zero_4bits** may be specified in the future by ITU-T | ISO/IEC. Decoders shall ignore the value of **reserved_zero_4bits**.

seq_parameter_set_id identifies the sequence parameter set that is referred to by the picture parameter set. The value of **seq_parameter_set_id** shall be in the range of 0 to 31, inclusive.

NOTE 2 – When feasible, encoders should use distinct values of **seq_parameter_set_id** when the values of other sequence parameter set syntax elements differ rather than changing the values of the syntax elements associated with a specific value of **seq_parameter_set_id**.

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. When **chroma_format_idc** is not present, it shall be inferred to be equal to 1 (4:2:0 chroma format).

residual_colour_transform_flag equal to 1 specifies that the residual colour transform is applied as specified in subclause 8.5. **residual_colour_transform_flag** equal to 0 specifies that the residual colour transform is not applied. When **residual_colour_transform_flag** is not present, it shall be inferred to be equal to 0.

bit_depth_luma_minus8 specifies the bit depth of the samples of the luma array and the value of the luma quantisation parameter range offset $QpBdOffset_Y$, as specified by

$$BitDepth_Y = 8 + bit_depth_luma_minus8 \quad (7-1)$$

$$QpBdOffset_Y = 6 * bit_depth_luma_minus8 \quad (7-2)$$

When **bit_depth_luma_minus8** is not present, it shall be inferred to be equal to 0. **bit_depth_luma_minus8** shall be in the range of 0 to 4, inclusive.

bit_depth_chroma_minus8 specifies the bit depth of the samples of the chroma arrays and the value of the chroma quantisation parameter range offset $QpBdOffset_C$, as specified by

$$BitDepth_C = 8 + bit_depth_chroma_minus8 \quad (7-3)$$

$$QpBdOffset_C = 6 * (bit_depth_chroma_minus8 + residual_colour_transform_flag) \quad (7-4)$$

When **bit_depth_chroma_minus8** is not present, it shall be inferred to be equal to 0. **bit_depth_chroma_minus8** shall be in the range of 0 to 4, inclusive.

The variable **RawMbBits** is derived as

$$RawMbBits = 256 * BitDepth_Y + 2 * MbWidthC * MbHeightC * BitDepth_C \quad (7-5)$$

qpprime_y_zero_transform_bypass_flag equal to 1 specifies that, when QP'_Y is equal to 0, a transform bypass operation for the transform coefficient decoding process and picture construction process prior to deblocking filter process as specified in subclause 8.5 shall be applied. **qpprime_y_zero_transform_bypass_flag** equal to 0 specifies that the transform coefficient decoding process and picture construction process prior to deblocking filter process shall not use the transform bypass operation. When **qpprime_y_zero_transform_bypass_flag** is not present, it shall be inferred to be equal to 0.

seq_scaling_matrix_present_flag equal to 1 specifies that the flags **seq_scaling_list_present_flag[i]** for $i = 0..7$ are present. **seq_scaling_matrix_present_flag** equal to 0 specifies that these flags are not present and the sequence-level scaling list specified by **Flat_4x4_16** shall be inferred for $i = 0..5$ and the sequence-level scaling list specified by **Flat_8x8_16** shall be inferred for $i = 6..7$. When **seq_scaling_matrix_present_flag** is not present, it shall be inferred to be equal to 0.

The scaling lists **Flat_4x4_16** and **Flat_8x8_16** are specified as follows:

$$\text{Flat_4x4_16}[i] = 16, \quad \text{with } i = 0..15, \quad (7-6)$$

$$\text{Flat_8x8_16}[i] = 16, \quad \text{with } i = 0..63. \quad (7-7)$$

seq_scaling_list_present_flag[i] equal to 1 specifies that the syntax structure for scaling list i is present in the sequence parameter set. **seq_scaling_list_present_flag[i]** equal to 0 specifies that the syntax structure for scaling list i is not present in the sequence parameter set and the scaling list fall-back rule set A specified in Table 7-2 shall be used to infer the sequence-level scaling list for index i .

Table 7-2 – Assignment of mnemonic names to scaling list indices and specification of fall-back rule

Value of scaling list index	Mnemonic name	Block size	MB prediction type	Component	Scaling list fall-back rule set A	Scaling list fall-back rule set B	Default scaling list
0	SI_4x4_Intra_Y	4x4	Intra	Y	default scaling list	sequence-level scaling list	Default_4x4_Intra
1	SI_4x4_Intra_Cb	4x4	Intra	Cb	scaling list for $i = 0$	scaling list for $i = 0$	Default_4x4_Intra
2	SI_4x4_Intra_Cr	4x4	Intra	Cr	scaling list for $i = 1$	scaling list for $i = 1$	Default_4x4_Intra
3	SI_4x4_Inter_Y	4x4	Inter	Y	default scaling list	sequence-level scaling list	Default_4x4_Inter
4	SI_4x4_Inter_Cb	4x4	Inter	Cb	scaling list for $i = 3$	scaling list for $i = 3$	Default_4x4_Inter
5	SI_4x4_Inter_Cr	4x4	Inter	Cr	scaling list for $i = 4$	scaling list for $i = 4$	Default_4x4_Inter
6	SI_8x8_Intra_Y	8x8	Intra	Y	default scaling list	sequence-level scaling list	Default_8x8_Intra
7	SI_8x8_Inter_Y	8x8	Inter	Y	default scaling list	sequence-level scaling list	Default_8x8_Inter

Table 7-3 specifies the default scaling lists **Default_4x4_Intra** and **Default_4x4_Inter**. Table 7-4 specifies the default scaling lists **Default_8x8_Intra** and **Default_8x8_Inter**.

Table 7-3 – Specification of default scaling lists Default_4x4_Intra and Default_4x4_Inter

idx	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Default_4x4_Intra[idx]	6	13	13	20	20	20	28	28	28	28	32	32	32	37	37	42
Default_4x4_Inter[idx]	10	14	14	20	20	20	24	24	24	24	27	27	27	30	30	34

Table 7-4 – Specification of default scaling lists Default_8x8_Intra and Default_8x8_Inter

idx	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Default_8x8_Intra[idx]	6	10	10	13	11	13	16	16	16	16	18	18	18	18	18	23
Default_8x8_Inter[idx]	9	13	13	15	13	15	17	17	17	17	19	19	19	19	19	21

Table 7-4 (continued) – Specification of default scaling lists Default_8x8_Intra and Default_8x8_Inter

idx	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Default_8x8_Intra[idx]	23	23	23	23	23	25	25	25	25	25	25	25	27	27	27	27
Default_8x8_Inter[idx]	21	21	21	21	21	22	22	22	22	22	22	22	24	24	24	24

Table 7-4 (continued) – Specification of default scaling lists Default_8x8_Intra and Default_8x8_Inter

idx	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Default_8x8_Intra[idx]	27	27	27	27	29	29	29	29	29	29	29	31	31	31	31	31
Default_8x8_Inter[idx]	24	24	24	24	25	25	25	25	25	25	25	27	27	27	27	27

Table 7-4 (concluded) – Specification of default scaling lists Default_8x8_Intra and Default_8x8_Inter

idx	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Default_8x8_Intra[idx]	31	33	33	33	33	33	36	36	36	36	38	38	38	40	40	42
Default_8x8_Inter[idx]	27	28	28	28	28	28	30	30	30	30	32	32	32	33	33	35

log2_max_frame_num_minus4 specifies the value of the variable MaxFrameNum that is used in frame_num related derivations as follows:

$$\text{MaxFrameNum} = 2^{(\text{log2_max_frame_num_minus4} + 4)} \quad (7-8)$$

The value of log2_max_frame_num_minus4 shall be in the range of 0 to 12, inclusive.

pic_order_cnt_type specifies the method to decode picture order count (as specified in subclause 8.2.1). The value of pic_order_cnt_type shall be in the range of 0 to 2, inclusive.

pic_order_cnt_type shall not be equal to 2 in a coded video sequence that contains any of the following

- an access unit containing a non-reference frame followed immediately by an access unit containing a non-reference picture;
- two access units each containing a field with the two fields together forming a complementary non-reference field pair followed immediately by an access unit containing a non-reference picture;
- an access unit containing a non-reference field followed immediately by an access unit containing another non-reference picture that does not form a complementary non-reference field pair with the first of the two access units.

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 specified in subclause 8.2.1 as follows:

$$\text{MaxPicOrderCntLsb} = 2^{(\text{log2_max_pic_order_cnt_lsb_minus4} + 4)} \quad (7-9)$$

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

delta_pic_order_always_zero_flag equal to 1 specifies that delta_pic_order_cnt[0] and delta_pic_order_cnt[1] are not present in the slice headers of the sequence and shall be inferred to be equal to 0. delta_pic_order_always_zero_flag equal to 0 specifies that delta_pic_order_cnt[0] is present in the slice headers of the sequence and delta_pic_order_cnt[1] may be present in the slice headers of the sequence.

offset_for_non_ref_pic is used to calculate the picture order count of a non-reference picture as specified in 8.2.1. The value of offset_for_non_ref_pic shall be in the range of -2^{31} to $2^{31} - 1$, inclusive.

offset_for_top_to_bottom_field is used to calculate the picture order count of a bottom field as specified in subclause 8.2.1. The value of offset_for_top_to_bottom_field shall be in the range of -2^{31} to $2^{31} - 1$, inclusive.

num_ref_frames_in_pic_order_cnt_cycle is used in the decoding process for picture order count as specified in subclause 8.2.1. The value of num_ref_frames_in_pic_order_cnt_cycle shall be in the range of 0 to 255, inclusive.

offset_for_ref_frame[i] is an element of a list of num_ref_frames_in_pic_order_cnt_cycle values used in the decoding process for picture order count as specified in subclause 8.2.1. The value of offset_for_ref_frame[i] shall be in the range of -2^{31} to $2^{31} - 1$, inclusive.

num_ref_frames specifies the maximum number of short-term and long-term reference frames, complementary reference field pairs, and non-paired reference fields that may be used by the decoding process for inter prediction of any picture in the sequence. num_ref_frames also determines the size of the sliding window operation as specified in subclause 8.2.5.3. The value of num_ref_frames shall be in the range of 0 to MaxDpbSize (as specified in subclause A.3.1 or A.3.2), inclusive.

gaps_in_frame_num_value_allowed_flag specifies the allowed values of frame_num as specified in subclause 7.4.3 and the decoding process in case of an inferred gap between values of frame_num as specified in subclause 8.2.5.2.

pic_width_in_mbs_minus1 plus 1 specifies the width of each decoded picture in units of macroblocks.

The variable for the picture width in units of macroblocks is derived as follows

$$\text{PicWidthInMbs} = \text{pic_width_in_mbs_minus1} + 1 \quad (7-10)$$

The variable for picture width for the luma component is derived as follows

$$\text{PicWidthInSamples}_L = \text{PicWidthInMbs} * 16 \quad (7-11)$$

The variable for picture width for the chroma components is derived as follows

$$\text{PicWidthInSamples}_C = \text{PicWidthInMbs} * \text{MbWidthC} \quad (7-12)$$

pic_height_in_map_units_minus1 plus 1 specifies the height in slice group map units of a decoded frame or field.

The variables PicHeightInMapUnits and PicSizeInMapUnits are derived as follows

$$\text{PicHeightInMapUnits} = \text{pic_height_in_map_units_minus1} + 1 \quad (7-13)$$

$$\text{PicSizeInMapUnits} = \text{PicWidthInMbs} * \text{PicHeightInMapUnits} \quad (7-14)$$

frame_mbs_only_flag equal to 0 specifies that coded pictures of the coded video sequence may either be coded fields or coded frames. frame_mbs_only_flag equal to 1 specifies that every coded picture of the coded video sequence is a coded frame containing only frame macroblocks.

The allowed range of values for pic_width_in_mbs_minus1, pic_height_in_map_units_minus1, and frame_mbs_only_flag is specified by constraints in Annex A.

Depending on `frame_mbs_only_flag`, semantics are assigned to `pic_height_in_map_units_minus1` as follows.

- If `frame_mbs_only_flag` is equal to 0, `pic_height_in_map_units_minus1` plus 1 is the height of a field in units of macroblocks.
- Otherwise (`frame_mbs_only_flag` is equal to 1), `pic_height_in_map_units_minus1` plus 1 is the height of a frame in units of macroblocks.

The variable `FrameHeightInMbs` is derived as follows

$$\text{FrameHeightInMbs} = (2 - \text{frame_mbs_only_flag}) * \text{PicHeightInMapUnits} \quad (7-15)$$

`mb_adaptive_frame_field_flag` equal to 0 specifies no switching between frame and field macroblocks within a picture. `mb_adaptive_frame_field_flag` equal to 1 specifies the possible use of switching between frame and field macroblocks within frames. When `mb_adaptive_frame_field_flag` is not present, it shall be inferred to be equal to 0.

`direct_8x8_inference_flag` specifies the method used in the derivation process for luma motion vectors for `B_Skip`, `B_Direct_16x16` and `B_Direct_8x8` as specified in subclause 8.4.1.2. When `frame_mbs_only_flag` is equal to 0, `direct_8x8_inference_flag` shall be equal to 1.

`frame_cropping_flag` equal to 1 specifies that the frame cropping offset parameters follow next in the sequence parameter set. `frame_cropping_flag` equal to 0 specifies that the frame cropping offset parameters are not present.

`frame_crop_left_offset`, `frame_crop_right_offset`, `frame_crop_top_offset`, `frame_crop_bottom_offset` specify the samples of the pictures in the coded video sequence that are output from the decoding process, in terms of a rectangular region specified in frame coordinates for output.

The variables `CropUnitX` and `CropUnitY` are derived as follows:

- If `chroma_format_idc` is equal to 0, `CropUnitX` and `CropUnitY` are derived as

$$\text{CropUnitX} = 1 \quad (7-16)$$

$$\text{CropUnitY} = 2 - \text{frame_mbs_only_flag} \quad (7-17)$$

- Otherwise (`chroma_format_idc` is equal to 1, 2, or 3), `CropUnitX` and `CropUnitY` are derived as

$$\text{CropUnitX} = \text{SubWidthC} \quad (7-18)$$

$$\text{CropUnitY} = \text{SubHeightC} * (2 - \text{frame_mbs_only_flag}) \quad (7-19)$$

The frame cropping rectangle contains luma samples with horizontal frame coordinates from `CropUnitX * frame_crop_left_offset` to `PicWidthInSamplesL - (CropUnitX * frame_crop_right_offset + 1)` and vertical frame coordinates from `CropUnitY * frame_crop_top_offset` to `(16 * FrameHeightInMbs) - (CropUnitY * frame_crop_bottom_offset + 1)`, inclusive. The value of `frame_crop_left_offset` shall be in the range of 0 to `(PicWidthInSamplesL / CropUnitX) - (frame_crop_right_offset + 1)`, inclusive; and the value of `frame_crop_top_offset` shall be in the range of 0 to `(16 * FrameHeightInMbs / CropUnitY) - (frame_crop_bottom_offset + 1)`, inclusive.

When `frame_cropping_flag` is equal to 0, the values of `frame_crop_left_offset`, `frame_crop_right_offset`, `frame_crop_top_offset`, and `frame_crop_bottom_offset` shall be inferred to be equal to 0.

When `chroma_format_idc` is not equal to 0, the corresponding specified samples of the two chroma arrays are the samples having frame coordinates $(x / \text{SubWidthC}, y / \text{SubHeightC})$, where (x, y) are the frame coordinates of the specified luma samples.

For decoded fields, the specified samples of the decoded field are the samples that fall within the rectangle specified in frame coordinates.

`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.

7.4.2.1.1 Scaling list semantics

`delta_scale` is used to derive the j -th element of the scaling list for j in the range of 0 to `sizeofScalingList - 1`, inclusive. The value of `delta_scale` shall be in the range of -128 to +127, inclusive.

When `useDefaultScalingMatrixFlag` is derived to be equal to 1, the scaling list shall be inferred to be equal to the default scaling list as specified in Table 7-2.

7.4.2.1.2 Sequence parameter set extension RBSP semantics

seq_parameter_set_id identifies the sequence parameter set associated with the sequence parameter set extension. The value of **seq_parameter_set_id** shall be in the range of 0 to 31, inclusive.

aux_format_idc equal to 0 indicates that there are no auxiliary coded pictures in the coded video sequence. **aux_format_idc** equal to 1 indicates that exactly one auxiliary coded picture is present in each access unit of the coded video sequence, and that for alpha blending purposes the decoded samples of the associated primary coded picture in each access unit should be multiplied by the interpretation sample values of the auxiliary coded picture in the access unit in the display process after output from the decoding process. **aux_format_idc** equal to 2 indicates that exactly one auxiliary coded picture exists in each access unit of the coded video sequence, and that for alpha blending purposes the decoded samples of the associated primary coded picture in each access unit should not be multiplied by the interpretation sample values of the auxiliary coded picture in the access unit in the display process after output from the decoding process. **aux_format_idc** equal to 3 indicates that exactly one auxiliary coded picture exists in each access unit of the coded video sequence, and that the usage of the auxiliary coded pictures is unspecified. The value of **aux_format_idc** shall be in the range of 0 to 3, inclusive. Values greater than 3 for **aux_format_idc** are reserved to indicate the presence of exactly one auxiliary coded picture in each access unit of the coded video sequence for purposes to be specified in the future by ITU-T | ISO/IEC. When **aux_format_idc** is not present, it shall be inferred to be equal to 0.

NOTE 1 – Decoders conforming to this Recommendation | International Standard are not required to decode auxiliary coded pictures.

bit_depth_aux_minus8 specifies the bit depth of the samples of the sample array of the auxiliary coded picture. **bit_depth_aux_minus8** shall be in the range of 0 to 4, inclusive.

alpha_incr_flag equal to 0 indicates that the interpretation sample value for each decoded auxiliary coded picture sample value is equal to the decoded auxiliary coded picture sample value for purposes of alpha blending. **alpha_incr_flag** equal to 1 indicates that, for purposes of alpha blending, after decoding the auxiliary coded picture samples, any auxiliary coded picture sample value that is greater than $\text{Min}(\text{alpha_opaque_value}, \text{alpha_transparent_value})$ should be increased by one to obtain the interpretation sample value for the auxiliary coded picture sample, and any auxiliary coded picture sample value that is less than or equal to $\text{Min}(\text{alpha_opaque_value}, \text{alpha_transparent_value})$ should be used without alteration as the interpretation sample value for the decoded auxiliary coded picture sample value.

alpha_opaque_value specifies the interpretation sample value of an auxiliary coded picture sample for which the associated luma and chroma samples of the same access unit are considered opaque for purposes of alpha blending. The number of bits used for the representation of the **alpha_opaque_value** syntax element is **bit_depth_aux_minus8** + 9 bits.

alpha_transparent_value specifies the interpretation sample value of an auxiliary coded picture sample for which the associated luma and chroma samples of the same access unit are considered transparent for purposes of alpha blending. The number of bits used for the representation of the **alpha_transparent_value** syntax element is **bit_depth_aux_minus8** + 9 bits.

When **alpha_incr_flag** is equal to 1, **alpha_transparent_value** shall not be equal to **alpha_opaque_value** and $\text{Log}_2(\text{Abs}(\text{alpha_opaque_value} - \text{alpha_transparent_value}))$ shall have an integer value. A value of **alpha_transparent_value** that is equal to **alpha_opaque_value** indicates that the auxiliary coded picture is not intended for alpha blending purposes.

NOTE 2 – For alpha blending purposes, **alpha_opaque_value** may be greater than **alpha_transparent_value**, or it may be less than **alpha_transparent_value**. Interpretation sample values should be clipped to the range of **alpha_opaque_value** to **alpha_transparent_value**, inclusive.

The decoding of the sequence parameter set extension and the decoding of auxiliary coded pictures is not required for conformance with this Recommendation | International Standard.

The syntax of each coded slice of an auxiliary coded picture shall obey the same constraints as a coded slice of a redundant picture, with the following differences of constraints.

- The following applies in regard to whether the primary coded picture is an IDR picture.
 - If the primary coded picture is an IDR picture, the auxiliary coded slice syntax shall correspond to that of a slice having **nal_unit_type** equal to 5 (a slice of an IDR picture);
 - Otherwise (the primary coded picture is not an IDR picture), the auxiliary coded slice syntax shall correspond to that of a slice having **nal_unit_type** equal to 1 (a slice of a non-IDR picture).
- The slices of an auxiliary coded picture (when present) shall contain all macroblocks corresponding to those of the primary coded picture.
- **redundant_pic_cnt** shall be equal to 0 in all auxiliary coded slices.

The (optional) decoding process for the decoding of auxiliary coded pictures is the same as if the auxiliary coded pictures were primary coded pictures in a separate coded video stream that differs from the primary coded pictures in the current coded video stream in the following ways.

- The IDR or non-IDR status of each auxiliary coded picture shall be inferred to be the same as the IDR or non-IDR status of the primary picture in the same access unit, rather than being inferred from the value of `nal_ref_idc`.
- The value of `chroma_format_idc` shall be inferred to be equal to 0 for the decoding of the auxiliary coded pictures.
- The value of `bit_depth_luma_minus8` shall be inferred to be equal to `bit_depth_aux_minus8` for the decoding of the auxiliary coded pictures.

NOTE 3 – Alpha blending composition is normally performed with a background picture B, a foreground picture F, and a decoded auxiliary coded picture A, all of the same size. Assume for purposes of example illustration that the chroma resolution of B and F have been upsampled to the same resolution as the luma. Denote corresponding samples of B, F and A by *b*, *f* and *a*, respectively. Denote luma and chroma samples by subscripts Y, Cb and Cr.

Define the variables `alphaRange`, `alphaFwt` and `alphaBwt` as follows:

$$\begin{aligned} \text{alphaRange} &= \text{Abs}(\text{alpha_opaque_value} - \text{alpha_transparent_value}) \\ \text{alphaFwt} &= \text{Abs}(a - \text{alpha_transparent_value}) \\ \text{alphaBwt} &= \text{Abs}(a - \text{alpha_opaque_value}) \end{aligned}$$

Then, in alpha blending composition, samples *d* of the displayed picture D may be calculated as

$$\begin{aligned} d_Y &= (\text{alphaFwt} * f_Y + \text{alphaBwt} * b_Y + \text{alphaRange}/2) / \text{alphaRange} \\ d_{CB} &= (\text{alphaFwt} * f_{CB} + \text{alphaBwt} * b_{CB} + \text{alphaRange}/2) / \text{alphaRange} \\ d_{CR} &= (\text{alphaFwt} * f_{CR} + \text{alphaBwt} * b_{CR} + \text{alphaRange}/2) / \text{alphaRange} \end{aligned}$$

The samples of pictures D, F and B could also represent red, green, and blue component values (see subclause E.2.1). Here we have assumed Y, Cb and Cr component values. Each component, e.g. Y, is assumed for purposes of example illustration above to have the same bit depth in each of the pictures D, F and B. However, different components, e.g. Y and Cb, need not have the same bit depth in this example.

When `aux_format_idc` is equal to 1, F would be the decoded picture obtained from the decoded luma and chroma, and A would be the decoded picture obtained from the decoded auxiliary coded picture. In this case, the indicated example alpha blending composition involves multiplying the samples of F by factors obtained from the samples of A.

A picture format that is useful for editing or direct viewing, and that is commonly used, is called pre-multiplied-black video. If the foreground picture was F, then the pre-multiplied-black video S is given by

$$\begin{aligned} s_Y &= (\text{alphaFwt} * f_Y) / \text{alphaRange} \\ s_{CB} &= (\text{alphaFwt} * f_{CB}) / \text{alphaRange} \\ s_{CR} &= (\text{alphaFwt} * f_{CR}) / \text{alphaRange} \end{aligned}$$

Pre-multiplied-black video has the characteristic that the picture S will appear correct if displayed against a black background. For a non-black background B, the composition of the displayed picture D may be calculated as

$$\begin{aligned} d_Y &= s_Y + (\text{alphaBwt} * b_Y + \text{alphaRange}/2) / \text{alphaRange} \\ d_{CB} &= s_{CB} + (\text{alphaBwt} * b_{CB} + \text{alphaRange}/2) / \text{alphaRange} \\ d_{CR} &= s_{CR} + (\text{alphaBwt} * b_{CR} + \text{alphaRange}/2) / \text{alphaRange} \end{aligned}$$

When `aux_format_idc` is equal to 2, S would be the decoded picture obtained from the decoded luma and chroma, and A would again be the decoded picture obtained from the decoded auxiliary coded picture. In this case, alpha blending composition does not involve multiplication of the samples of S by factors obtained from the samples of A.

additional_extension_flag equal to 0 indicates that no additional data follows within the sequence parameter set extension syntax structure prior to the Rbsp trailing bits. The value of `additional_extension_flag` shall be equal to 0. The value of 1 for `additional_extension_flag` is reserved for future use by ITU-T | ISO/IEC. Decoders that conform to this Recommendation | International Standard shall ignore all data that follows the value of 1 for `additional_extension_flag` in a sequence parameter set extension NAL unit.

7.4.2.2 Picture parameter set Rbsp semantics

pic_parameter_set_id identifies the picture parameter set that is referred to in the slice header. The value of `pic_parameter_set_id` shall be in the range of 0 to 255, inclusive.

seq_parameter_set_id refers to the active sequence parameter set. The value of `seq_parameter_set_id` shall be in the range of 0 to 31, inclusive.

entropy_coding_mode_flag selects the entropy decoding method to be applied for the syntax elements for which two descriptors appear in the syntax tables as follows.

- If `entropy_coding_mode_flag` is equal to 0, the method specified by the left descriptor in the syntax table is applied (Exp-Golomb coded, see subclause 9.1 or CAVLC, see subclause 9.2).
- Otherwise (`entropy_coding_mode_flag` is equal to 1), the method specified by the right descriptor in the syntax table is applied (CABAC, see subclause 9.3).

pic_order_present_flag equal to 1 specifies that the picture order count related syntax elements are present in the slice headers as specified in subclause 7.3.3. **pic_order_present_flag** equal to 0 specifies that the picture order count related syntax elements are not present in the slice headers.

num_slice_groups_minus1 plus 1 specifies the number of slice groups for a picture. When **num_slice_groups_minus1** is equal to 0, all slices of the picture belong to the same slice group. The allowed range of **num_slice_groups_minus1** is specified in Annex A.

slice_group_map_type specifies how the mapping of slice group map units to slice groups is coded. The value of **slice_group_map_type** shall be in the range of 0 to 6, inclusive.

slice_group_map_type equal to 0 specifies interleaved slice groups.

slice_group_map_type equal to 1 specifies a dispersed slice group mapping.

slice_group_map_type equal to 2 specifies one or more “foreground” slice groups and a “leftover” slice group.

slice_group_map_type values equal to 3, 4, and 5 specify changing slice groups. When **num_slice_groups_minus1** is not equal to 1, **slice_group_map_type** shall not be equal to 3, 4, or 5.

slice_group_map_type equal to 6 specifies an explicit assignment of a slice group to each slice group map unit.

Slice group map units are specified as follows.

- If **frame_mbs_only_flag** is equal to 0 and **mb_adaptive_frame_field_flag** is equal to 1 and the coded picture is a frame, the slice group map units are macroblock pair units.
- Otherwise, if **frame_mbs_only_flag** is equal to 1 or a coded picture is a field, the slice group map units are units of macroblocks.
- Otherwise (**frame_mbs_only_flag** is equal to 0 and **mb_adaptive_frame_field_flag** is equal to 0 and the coded picture is a frame), the slice group map units are units of two macroblocks that are vertically contiguous as in a frame macroblock pair of an MBAFF frame.

run_length_minus1[i] is used to specify the number of consecutive slice group map units to be assigned to the *i*-th slice group in raster scan order of slice group map units. The value of **run_length_minus1[i]** shall be in the range of 0 to **PicSizeInMapUnits** - 1, inclusive.

top_left[i] and **bottom_right[i]** specify the top-left and bottom-right corners of a rectangle, respectively. **top_left[i]** and **bottom_right[i]** are slice group map unit positions in a raster scan of the picture for the slice group map units. For each rectangle *i*, all of the following constraints shall be obeyed by the values of the syntax elements **top_left[i]** and **bottom_right[i]**

- **top_left[i]** shall be less than or equal to **bottom_right[i]** and **bottom_right[i]** shall be less than **PicSizeInMapUnits**.
- $(\text{top_left}[i] \% \text{PicWidthInMbs})$ shall be less than or equal to the value of $(\text{bottom_right}[i] \% \text{PicWidthInMbs})$.

slice_group_change_direction_flag is used with **slice_group_map_type** to specify the refined map type when **slice_group_map_type** is 3, 4, or 5.

slice_group_change_rate_minus1 is used to specify the variable **SliceGroupChangeRate**. **SliceGroupChangeRate** specifies the multiple in number of slice group map units by which the size of a slice group can change from one picture to the next. The value of **slice_group_change_rate_minus1** shall be in the range of 0 to **PicSizeInMapUnits** - 1, inclusive. The **SliceGroupChangeRate** variable is specified as follows:

$$\text{SliceGroupChangeRate} = \text{slice_group_change_rate_minus1} + 1 \quad (7-20)$$

pic_size_in_map_units_minus1 is used to specify the number of slice group map units in the picture. **pic_size_in_map_units_minus1** shall be equal to **PicSizeInMapUnits** - 1.

slice_group_id[i] identifies a slice group of the *i*-th slice group map unit in raster scan order. The size of the **slice_group_id[i]** syntax element is $\text{Ceil}(\text{Log}_2(\text{num_slice_groups_minus1} + 1))$ bits. The value of **slice_group_id[i]** shall be in the range of 0 to **num_slice_groups_minus1**, inclusive.

num_ref_idx_l0_active_minus1 specifies the maximum reference index for reference picture list 0 that shall be used to decode each slice of the picture in which list 0 prediction is used when **num_ref_idx_active_override_flag** is equal to 0 for the slice. When **MbaffFrameFlag** is equal to 1, **num_ref_idx_l0_active_minus1** is the maximum index value for the decoding of frame macroblocks and $2 * \text{num_ref_idx_l0_active_minus1} + 1$ is the maximum index value for the decoding of field macroblocks. The value of **num_ref_idx_l0_active_minus1** shall be in the range of 0 to 31, inclusive.

num_ref_idx_l1_active_minus1 has the same semantics as num_ref_idx_l0_active_minus1 with l0 and list 0 replaced by l1 and list 1, respectively.

weighted_pred_flag equal to 0 specifies that weighted prediction shall not be applied to P and SP slices. **weighted_pred_flag** equal to 1 specifies that weighted prediction shall be applied to P and SP slices.

weighted_bipred_idc equal to 0 specifies that the default weighted prediction shall be applied to B slices. **weighted_bipred_idc** equal to 1 specifies that explicit weighted prediction shall be applied to B slices. **weighted_bipred_idc** equal to 2 specifies that implicit weighted prediction shall be applied to B slices. The value of **weighted_bipred_idc** shall be in the range of 0 to 2, inclusive.

pic_init_qp_minus26 specifies the initial value minus 26 of QP_Y for each slice. The initial value is modified at the slice layer when a non-zero value of **slice_qp_delta** is decoded, and is modified further when a non-zero value of **mb_qp_delta** is decoded at the macroblock layer. The value of **pic_init_qp_minus26** shall be in the range of $-(26 + QpBdOffset_Y)$ to +25, inclusive.

pic_init_qs_minus26 specifies the initial value minus 26 of QS_Y for all macroblocks in SP or SI slices. The initial value is modified at the slice layer when a non-zero value of **slice_qs_delta** is decoded. The value of **pic_init_qs_minus26** shall be in the range of -26 to +25, inclusive.

chroma_qp_index_offset specifies the offset that shall be added to QP_Y and QS_Y for addressing the table of QP_C values for the Cb chroma component. The value of **chroma_qp_index_offset** shall be in the range of -12 to +12, inclusive.

deblocking_filter_control_present_flag equal to 1 specifies that a set of syntax elements controlling the characteristics of the deblocking filter is present in the slice header. **deblocking_filter_control_present_flag** equal to 0 specifies that the set of syntax elements controlling the characteristics of the deblocking filter is not present in the slice headers and their inferred values are in effect.

constrained_intra_pred_flag equal to 0 specifies that intra prediction allows usage of residual data and decoded samples of neighbouring macroblocks coded using Inter macroblock prediction modes for the prediction of macroblocks coded using Intra macroblock prediction modes. **constrained_intra_pred_flag** equal to 1 specifies constrained intra prediction, in which case prediction of macroblocks coded using Intra macroblock prediction modes only uses residual data and decoded samples from I or SI macroblock types.

redundant_pic_cnt_present_flag equal to 0 specifies that the **redundant_pic_cnt** syntax element is not present in slice headers, data partitions B, and data partitions C that refer (either directly or by association with a corresponding data partition A) to the picture parameter set. **redundant_pic_cnt_present_flag** equal to 1 specifies that the **redundant_pic_cnt** syntax element is present in all slice headers, data partitions B, and data partitions C that refer (either directly or by association with a corresponding data partition A) to the picture parameter set.

transform_8x8_mode_flag equal to 1 specifies that the 8x8 transform decoding process may be in use (see subclause 8.5). **transform_8x8_mode_flag** equal to 0 specifies that the 8x8 transform decoding process is not in use. When **transform_8x8_mode_flag** is not present, it shall be inferred to be 0.

pic_scaling_matrix_present_flag equal to 1 specifies that parameters are present to modify the scaling lists specified in the sequence parameter set. **pic_scaling_matrix_present_flag** equal to 0 specifies that the scaling lists used for the picture shall be inferred to be equal to those specified by the sequence parameter set. When **pic_scaling_matrix_present_flag** is not present, it shall be inferred to be equal to 0.

pic_scaling_list_present_flag[i] equal to 1 specifies that the scaling list syntax structure is present to specify the scaling list for index i. **pic_scaling_list_present_flag[i]** equal to 0 specifies that the syntax structure for scaling list i is not present in the picture parameter set and that depending on the value of **seq_scaling_matrix_present_flag**, the following applies.

- If **seq_scaling_matrix_present_flag** is equal to 0, the scaling list fall-back rule set A as specified in Table 7-2 shall be used to derive the picture-level scaling list for index i.
- Otherwise (**seq_scaling_matrix_present_flag** is equal to 1), the scaling list fall-back rule set B as specified in Table 7-2 shall be used to derive the picture-level scaling list for index i.

second_chroma_qp_index_offset specifies the offset that shall be added to QP_Y and QS_Y for addressing the table of QP_C values for the Cr chroma component. The value of **second_chroma_qp_index_offset** shall be in the range of -12 to +12, inclusive.

When **second_chroma_qp_index_offset** is not present, it shall be inferred to be equal to **chroma_qp_index_offset**.

7.4.2.3 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.

7.4.2.3.1 Supplemental enhancement information message semantics

An SEI NAL unit contains one or more SEI messages. Each SEI message consists of the variables specifying the type payloadType and size payloadSize of the SEI payload. SEI payloads are specified in Annex D. The derived SEI payload size payloadSize is specified in bytes and shall be equal to the number of bytes in the 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 size of an SEI message.

7.4.2.4 Access unit delimiter RBSP semantics

The access unit delimiter may be used to indicate the type of slices present in a primary 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.

primary_pic_type indicates that the slice_type values for all slices of the primary coded picture are members of the set listed in Table 7-5 for the given value of primary_pic_type.

Table 7-5 – Meaning of primary_pic_type

primary_pic_type	slice_type values that may be present in the primary coded picture
0	I
1	I, P
2	I, P, B
3	SI
4	SI, SP
5	I, SI
6	I, SI, P, SP
7	I, SI, P, SP, B

7.4.2.5 End of sequence RBSP semantics

The end of sequence RBSP specifies that the next subsequent access unit in the bitstream in decoding order (if any) shall be an IDR access unit. The syntax content of the SODB and RBSP for the end of sequence RBSP are empty. No normative decoding process is specified for an end of sequence RBSP.

7.4.2.6 End of stream RBSP semantics

The end of stream RBSP indicates that no additional NAL units shall be present in the bitstream that are subsequent to the end of stream RBSP in decoding order. The syntax content of the SODB and RBSP for the end of stream RBSP are empty. No normative decoding process is specified for an end of stream RBSP.

7.4.2.7 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.

7.4.2.8 Slice layer without partitioning RBSP semantics

The slice layer without partitioning RBSP consists of a slice header and slice data.

7.4.2.9 Slice data partition RBSP semantics

7.4.2.9.1 Slice data partition A RBSP semantics

When slice data partitioning is in use, the coded data for a single slice is divided into three separate partitions. Partition A contains all syntax elements of category 2.

Category 2 syntax elements include all syntax elements in the slice header and slice data syntax structures other than the syntax elements in the residual() syntax structure.

slice_id identifies the slice associated with the data partition. Each slice shall have a unique slice_id value within the coded picture that contains the slice. When arbitrary slice order is not allowed as specified in Annex A, the first slice of a coded picture, in decoding order, shall have slice_id equal to 0 and the value of slice_id shall be incremented by one for each subsequent slice of the coded picture in decoding order.

The range of slice_id is specified as follows.

- If MbaffFrameFlag is equal to 0, slice_id shall be in the range of 0 to PicSizeInMbs - 1, inclusive.
- Otherwise (MbaffFrameFlag is equal to 1), slice_id shall be in the range of 0 to PicSizeInMbs / 2 - 1, inclusive.

7.4.2.9.2 Slice data partition B RBSP semantics

When slice data partitioning is in use, the coded data for a single slice is divided into one to three separate partitions. Slice data partition B contains all syntax elements of category 3.

Category 3 syntax elements include all syntax elements in the residual() syntax structure and in syntax structures used within that syntax structure for collective macroblock types I and SI as specified in Table 7-10.

slice_id has the same semantics as specified in subclause 7.4.2.9.1.

redundant_pic_cnt shall be equal to 0 for slices and slice data partitions belonging to the primary coded picture. The redundant_pic_cnt shall be greater than 0 for coded slices and coded slice data partitions in redundant coded pictures. When redundant_pic_cnt is not present, its value shall be inferred to be equal to 0. The value of redundant_pic_cnt shall be in the range of 0 to 127, inclusive.

The presence of a slice data partition B RBSP is specified as follows.

- If the syntax elements of a slice data partition A RBSP indicate the presence of any syntax elements of category 3 in the slice data for a slice, a slice data partition B RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.
- Otherwise (the syntax elements of a slice data partition A RBSP do not indicate the presence of any syntax elements of category 3 in the slice data for a slice), no slice data partition B RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.

7.4.2.9.3 Slice data partition C RBSP semantics

When slice data partitioning is in use, the coded data for a single slice is divided into three separate partitions. Slice data partition C contains all syntax elements of category 4.

Category 4 syntax elements include all syntax elements in the residual() syntax structure and in syntax structures used within that syntax structure for collective macroblock types P and B as specified in Table 7-10.

slice_id has the same semantics as specified in subclause 7.4.2.9.1.

redundant_pic_cnt has the same semantics as specified in subclause 7.4.2.9.2.

The presence of a slice data partition C RBSP is specified as follows.

- If the syntax elements of a slice data partition A RBSP indicate the presence of any syntax elements of category 4 in the slice data for a slice, a slice data partition C RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.
- Otherwise (the syntax elements of a slice data partition A RBSP do not indicate the presence of any syntax elements of category 4 in the slice data for a slice), no slice data partition C RBSP shall be present having the same value of slice_id and redundant_pic_cnt as in the slice data partition A RBSP.

7.4.2.10 RBSP slice 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 9.3.3.2, is invoked to decode the contents of all VCL NAL units of a coded picture. When entropy_coding_mode_flag is equal to 1, BinCountsInNALunits shall not exceed $(32 \div 3) * \text{NumBytesInVclNALunits} + (\text{RawMbBits} * \text{PicSizeInMbs}) \div 32$.

NOTE – The constraint on the maximum number of bins resulting from decoding the contents of the slice layer 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).

7.4.2.11 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 Slice header semantics

When present, the value of the slice header syntax elements pic_parameter_set_id, frame_num, field_pic_flag, bottom_field_flag, idr_pic_id, pic_order_cnt_lsb, delta_pic_order_cnt_bottom, delta_pic_order_cnt[0], delta_pic_order_cnt[1], sp_for_switch_flag, and slice_group_change_cycle shall be the same in all slice headers of a coded picture.

first_mb_in_slice specifies the address of the first macroblock in the slice. When arbitrary slice order is not allowed as specified in Annex A, the value of first_mb_in_slice shall not be less than the value of first_mb_in_slice for any other slice of the current picture that precedes the current slice in decoding order.

The first macroblock address of the slice is derived as follows.

- If MbaffFrameFlag is equal to 0, first_mb_in_slice is the macroblock address of the first macroblock in the slice, and first_mb_in_slice shall be in the range of 0 to PicSizeInMbs - 1, inclusive.
- Otherwise (MbaffFrameFlag is equal to 1), first_mb_in_slice * 2 is the macroblock address of the first macroblock in the slice, which is the top macroblock of the first macroblock pair in the slice, and first_mb_in_slice shall be in the range of 0 to PicSizeInMbs / 2 - 1, inclusive.

slice_type specifies the coding type of the slice according to Table 7-6.

Table 7-6 – Name association to slice_type

slice_type	Name of slice_type
0	P (P slice)
1	B (B slice)
2	I (I slice)
3	SP (SP slice)
4	SI (SI slice)
5	P (P slice)
6	B (B slice)
7	I (I slice)
8	SP (SP slice)
9	SI (SI slice)

slice_type values in the range 5..9 specify, in addition to the coding type of the current slice, that all other slices of the current coded picture shall have a value of slice_type equal to the current value of slice_type or equal to the current value of slice_type - 5.

When nal_unit_type is equal to 5 (IDR picture), slice_type shall be equal to 2, 4, 7, or 9.

When num_ref_frames is equal to 0, slice_type shall be equal to 2, 4, 7, or 9.

pic_parameter_set_id specifies the picture parameter set in use. The value of pic_parameter_set_id shall be in the range of 0 to 255, inclusive.

frame_num is used as an identifier for pictures and shall be represented by $\log_2 \text{max_frame_num_minus4} + 4$ bits in the bitstream. **frame_num** is constrained as follows:

The variable **PrevRefFrameNum** is derived as follows.

- If the current picture is an IDR picture, **PrevRefFrameNum** is set equal to 0.
- Otherwise (the current picture is not an IDR picture), **PrevRefFrameNum** is set as follows.
 - If the decoding process for gaps in **frame_num** specified in subclause 8.2.5.2 was invoked by the decoding process for an access unit that contained a non-reference picture that followed the previous access unit in decoding order that contained a reference picture, **PrevRefFrameNum** is set equal to the value of **frame_num** for the last of the "non-existing" reference frames inferred by the decoding process for gaps in **frame_num** specified in subclause 8.2.5.2.
 - Otherwise, **PrevRefFrameNum** is set equal to the value of **frame_num** for the previous access unit in decoding order that contained a reference picture.

The value of **frame_num** is constrained as follows.

- If the current picture is an IDR picture, **frame_num** shall be equal to 0.
- Otherwise (the current picture is not an IDR picture), referring to the primary coded picture in the previous access unit in decoding order that contains a reference picture as the preceding reference picture, the value of **frame_num** for the current picture shall not be equal to **PrevRefFrameNum** unless all of the following three conditions are true.
 - the current picture and the preceding reference picture belong to consecutive access units in decoding order
 - the current picture and the preceding reference picture are reference fields having opposite parity
 - one or more of the following conditions is true
 - the preceding reference picture is an IDR picture
 - the preceding reference picture includes a **memory_management_control_operation** syntax element equal to 5
 - NOTE 1 – When the preceding reference picture includes a **memory_management_control_operation** syntax element equal to 5, **PrevRefFrameNum** is equal to 0.
 - there is a primary coded picture that precedes the preceding reference picture and the primary coded picture that precedes the preceding reference picture does not have **frame_num** equal to **PrevRefFrameNum**
 - there is a primary coded picture that precedes the preceding reference picture and the primary coded picture that precedes the preceding reference picture is not a reference picture

When the value of **frame_num** is not equal to **PrevRefFrameNum**, the following applies.

- There shall not be any previous field or frame in decoding order that is currently marked as "used for short-term reference" that has a value of **frame_num** equal to any value taken on by the variable **UnusedShortTermFrameNum** in the following:

```
UnusedShortTermFrameNum = ( PrevRefFrameNum + 1 ) % MaxFrameNum
while( UnusedShortTermFrameNum != frame_num )
    UnusedShortTermFrameNum = ( UnusedShortTermFrameNum + 1 ) % MaxFrameNum
```

(7-21)

- The value of **frame_num** is constrained as follows.
 - If **gaps_in_frame_num_value_allowed_flag** is equal to 0, the value of **frame_num** for the current picture shall be equal to $(\text{PrevRefFrameNum} + 1) \% \text{MaxFrameNum}$.
 - Otherwise (**gaps_in_frame_num_value_allowed_flag** is equal to 1), the following applies.
 - If **frame_num** is greater than **PrevRefFrameNum**, there shall not be any non-reference pictures in the bitstream that follow the previous reference picture and precede the current picture in decoding order in which either of the following conditions is true.
 - The value of **frame_num** for the non-reference picture is less than **PrevRefFrameNum**.
 - The value of **frame_num** for the non-reference picture is greater than the value of **frame_num** for the current picture.

- Otherwise (frame_num is less than PrevRefFrameNum), there shall not be any non-reference pictures in the bitstream that follow the previous reference picture and precede the current picture in decoding order in which both of the following conditions are true.
 - The value of frame_num for the non-reference picture is less than PrevRefFrameNum.
 - The value of frame_num for the non-reference picture is greater than the value of frame_num for the current picture.

A picture including a memory_management_control_operation equal to 5 shall have frame_num constraints as described above and, after the decoding of the current picture and the processing of the memory management control operations, the picture shall be inferred to have had frame_num equal to 0 for all subsequent use in the decoding process, except as specified in subclause 7.4.1.2.4.

NOTE 2 – When the primary coded picture is not an IDR picture and does not contain memory_management_control_operation syntax element equal to 5, the value of frame_num of a corresponding redundant coded picture is the same as the value of frame_num in the primary coded picture. Alternatively, the redundant coded picture includes a memory_management_control_operation syntax element equal to 5 and the corresponding primary coded picture is an IDR picture.

field_pic_flag equal to 1 specifies that the slice is a slice of a coded field. field_pic_flag equal to 0 specifies that the slice is a slice of a coded frame. When field_pic_flag is not present it shall be inferred to be equal to 0.

The variable MbaffFrameFlag is derived as follows.

$$\text{MbaffFrameFlag} = (\text{mb_adaptive_frame_field_flag} \ \&\& \ !\text{field_pic_flag}) \quad (7-22)$$

The variable for the picture height in units of macroblocks is derived as follows

$$\text{PicHeightInMbs} = \text{FrameHeightInMbs} / (1 + \text{field_pic_flag}) \quad (7-23)$$

The variable for picture height for the luma component is derived as follows

$$\text{PicHeightInSamples}_L = \text{PicHeightInMbs} * 16 \quad (7-24)$$

The variable for picture height for the chroma component is derived as follows

$$\text{PicHeightInSamples}_C = \text{PicHeightInMbs} * \text{MbHeightC} \quad (7-25)$$

The variable PicSizeInMbs for the current picture is derived according to:

$$\text{PicSizeInMbs} = \text{PicWidthInMbs} * \text{PicHeightInMbs} \quad (7-26)$$

The variable MaxPicNum is derived as follows.

- If field_pic_flag is equal to 0, MaxPicNum is set equal to MaxFrameNum.
- Otherwise (field_pic_flag is equal to 1), MaxPicNum is set equal to 2*MaxFrameNum.

The variable CurrPicNum is derived as follows.

- If field_pic_flag is equal to 0, CurrPicNum is set equal to frame_num.
- Otherwise (field_pic_flag is equal to 1), CurrPicNum is set equal to 2 * frame_num + 1.

bottom_field_flag equal to 1 specifies that the slice is part of a coded bottom field. bottom_field_flag equal to 0 specifies that the picture is a coded top field. When this syntax element is not present for the current slice, it shall be inferred to be equal to 0.

idr_pic_id identifies an IDR picture. The values of idr_pic_id in all the slices of an IDR picture shall remain unchanged. When two consecutive access units in decoding order are both IDR access units, the value of idr_pic_id in the slices of the first such IDR access unit shall differ from the idr_pic_id in the second such IDR access unit. The value of idr_pic_id shall be in the range of 0 to 65535, inclusive.

pic_order_cnt_lsb specifies the picture order count modulo MaxPicOrderCntLsb for the top field of a coded frame or for a coded field. The size of the pic_order_cnt_lsb syntax element is log2_max_pic_order_cnt_lsb_minus4 + 4 bits. The value of the pic_order_cnt_lsb shall be in the range of 0 to MaxPicOrderCntLsb – 1, inclusive.

delta_pic_order_cnt_bottom specifies the picture order count difference between the bottom field and the top field of a coded frame as follows.

- If the current picture includes a `memory_management_control_operation` equal to 5, the value of `delta_pic_order_cnt_bottom` shall be in the range of $(1 - \text{MaxPicOrderCntLsb})$ to $2^{31} - 1$, inclusive.
- Otherwise (the current picture does not include a `memory_management_control_operation` equal to 5), the value of `delta_pic_order_cnt_bottom` shall be in the range of -2^{31} to $2^{31} - 1$, inclusive.

When this syntax element is not present in the bitstream for the current slice, it shall be inferred to be equal to 0.

delta_pic_order_cnt[0] specifies the picture order count difference from the expected picture order count for the top field of a coded frame or for a coded field as specified in subclause 8.2.1. The value of `delta_pic_order_cnt[0]` shall be in the range of -2^{31} to $2^{31} - 1$, inclusive. When this syntax element is not present in the bitstream for the current slice, it shall be inferred to be equal to 0.

delta_pic_order_cnt[1] specifies the picture order count difference from the expected picture order count for the bottom field of a coded frame specified in subclause 8.2.1. The value of `delta_pic_order_cnt[1]` shall be in the range of -2^{31} to $2^{31} - 1$, inclusive. When this syntax element is not present in the bitstream for the current slice, it shall be inferred to be equal to 0.

redundant_pic_cnt shall be equal to 0 for slices and slice data partitions belonging to the primary coded picture. The value of `redundant_pic_cnt` shall be greater than 0 for coded slices or coded slice data partitions of a redundant coded picture. When `redundant_pic_cnt` is not present in the bitstream, its value shall be inferred to be equal to 0. The value of `redundant_pic_cnt` shall be in the range of 0 to 127, inclusive.

NOTE 3 – Any area of the decoded primary picture and the corresponding area that would result from application of the decoding process specified in clause 8 for any redundant picture in the same access unit should be visually similar in appearance.

The value of `pic_parameter_set_id` in a coded slice or coded slice data partition of a redundant coded picture shall be such that the value of `pic_order_present_flag` in the picture parameter set in use in a redundant coded picture is equal to the value of `pic_order_present_flag` in the picture parameter set in use in the corresponding primary coded picture.

When present in the primary coded picture and any redundant coded picture, the following syntax elements shall have the same value: `field_pic_flag`, `bottom_field_flag`, and `idr_pic_id`.

When the value of `nal_ref_idc` in one VCL NAL unit of an access unit is equal to 0, the value of `nal_ref_idc` in all other VCL NAL units of the same access unit shall be equal to 0.

NOTE 4 – The above constraint also has the following implications. If the value of `nal_ref_idc` for the VCL NAL units of the primary coded picture is equal to 0, the value of `nal_ref_idc` for the VCL NAL units of any corresponding redundant coded picture are equal to 0; otherwise (the value of `nal_ref_idc` for the VCL NAL units of the primary coded picture is greater than 0), the value of `nal_ref_idc` for the VCL NAL units of any corresponding redundant coded picture are also greater than 0.

The marking status of reference pictures and the value of `frame_num` after the decoded reference picture marking process as specified in subclause 8.2.5 is invoked for the primary coded picture or any redundant coded picture of the same access unit shall be identical regardless whether the primary coded picture or any redundant coded picture (instead of the primary coded picture) of the access unit would be decoded.

NOTE 5 – The above constraint also has the following implications.

If a primary coded picture is not an IDR picture, the contents of the `dec_ref_pic_marking()` syntax structure must be identical in all slice headers of the primary coded picture and all redundant coded pictures corresponding to the primary coded picture.

Otherwise (a primary coded picture is an IDR picture), the following applies.

If a redundant coded picture corresponding to the primary coded picture is an IDR picture, the contents of the `dec_ref_pic_marking()` syntax structure must be identical in all slice headers of the primary coded picture and the redundant coded picture corresponding to the primary coded picture.

Otherwise (a redundant picture corresponding to the primary coded picture is not an IDR picture), all slice headers of the redundant picture must contain a `dec_ref_pic_marking` syntax() structure including a `memory_management_control_operation` syntax element equal to 5, and the following applies.

If the value of `long_term_reference_flag` in the primary coded picture is equal to 0, the `dec_ref_pic_marking` syntax structure of the redundant coded picture must not include a `memory_management_control_operation` syntax element equal to 6.

Otherwise (the value of `long_term_reference_flag` in the primary coded picture is equal to 1), the `dec_ref_pic_marking` syntax structure of the redundant coded picture must include `memory_management_control_operation` syntax elements equal to 5, 4, and 6 in decoding order, and the value of `max_long_term_frame_idx_plus1` must be equal to 1, and the value of `long_term_frame_idx` must be equal to 0.

The values of `TopFieldOrderCnt` and `BottomFieldOrderCnt` (if applicable) that result after completion of the decoding process for any redundant coded picture or the primary coded picture of the same access unit shall be identical regardless whether the primary coded picture or any redundant coded picture (instead of the primary coded picture) of the access unit would be decoded.

There is no required decoding process for a coded slice or coded slice data partition of a redundant coded picture. When the `redundant_pic_cnt` in the slice header of a coded slice is greater than 0, the decoder may discard the coded slice. However, a coded slice or coded slice data partition of any redundant coded picture shall obey the same constraints as a coded slice or coded slice data partition of a primary picture.

NOTE 6 – When some of the samples in the decoded primary picture cannot be correctly decoded due to errors or losses in transmission of the sequence and a coded redundant slice can be correctly decoded, the decoder should replace the samples of the decoded primary picture with the corresponding samples of the decoded redundant slice. When more than one redundant slice covers the relevant region of the primary picture, the redundant slice having the lowest value of `redundant_pic_cnt` should be used.

Redundant slices and slice data partitions having the same value of `redundant_pic_cnt` belong to the same redundant picture. Decoded slices within the same redundant picture need not cover the entire picture area and shall not overlap.

direct_spatial_mv_pred_flag specifies the method used in the decoding process to derive motion vectors and reference indices for inter prediction as follows.

- If `direct_spatial_mv_pred_flag` is equal to 1, the derivation process for luma motion vectors for `B_Skip`, `B_Direct_16x16`, and `B_Direct_8x8` in subclause 8.4.1.2 shall use spatial direct mode prediction as specified in subclause 8.4.1.2.2.
- Otherwise (`direct_spatial_mv_pred_flag` is equal to 0), the derivation process for luma motion vectors for `B_Skip`, `B_Direct_16x16`, and `B_Direct_8x8` in subclause 8.4.1.2 shall use temporal direct mode prediction as specified in subclause 8.4.1.2.3.

num_ref_idx_active_override_flag equal to 0 specifies that the values of the syntax elements `num_ref_idx_l0_active_minus1` and `num_ref_idx_l1_active_minus1` specified in the referred picture parameter set are in effect. `num_ref_idx_active_override_flag` equal to 1 specifies that the `num_ref_idx_l0_active_minus1` and `num_ref_idx_l1_active_minus1` specified in the referred picture parameter set are overridden for the current slice (and only for the current slice) by the following values in the slice header.

When the current slice is a P, SP, or B slice and `field_pic_flag` is equal to 0 and the value of `num_ref_idx_l0_active_minus1` in the picture parameter set exceeds 15, `num_ref_idx_active_override_flag` shall be equal to 1.

When the current slice is a B slice and `field_pic_flag` is equal to 0 and the value of `num_ref_idx_l1_active_minus1` in the picture parameter set exceeds 15, `num_ref_idx_active_override_flag` shall be equal to 1.

num_ref_idx_l0_active_minus1 specifies the maximum reference index for reference picture list 0 that shall be used to decode the slice.

The range of `num_ref_idx_l0_active_minus1` is specified as follows.

- If `field_pic_flag` is equal to 0, `num_ref_idx_l0_active_minus1` shall be in the range of 0 to 15, inclusive. When `MbaffFrameFlag` is equal to 1, `num_ref_idx_l0_active_minus1` is the maximum index value for the decoding of frame macroblocks and $2 * \text{num_ref_idx_l0_active_minus1} + 1$ is the maximum index value for the decoding of field macroblocks.
- Otherwise (`field_pic_flag` is equal to 1), `num_ref_idx_l0_active_minus1` shall be in the range of 0 to 31, inclusive.

num_ref_idx_l1_active_minus1 has the same semantics as `num_ref_idx_l0_active_minus1` with l0 and list 0 replaced by l1 and list 1, respectively.

cabac_init_idc specifies the index for determining the initialisation table used in the initialisation process for context variables. The value of `cabac_init_idc` shall be in the range of 0 to 2, inclusive.

slice_qp_delta specifies the initial value of QP_Y to be used for all the macroblocks in the slice until modified by the value of `mb_qp_delta` in the macroblock layer. The initial QP_Y quantisation parameter for the slice is computed as:

$$\text{SliceQP}_Y = 26 + \text{pic_init_qp_minus26} + \text{slice_qp_delta} \quad (7-27)$$

The value of `slice_qp_delta` shall be limited such that SliceQP_Y is in the range of $-\text{QpBdOffset}_Y$ to +51, inclusive.

sp_for_switch_flag specifies the decoding process to be used to decode P macroblocks in an SP slice as follows.

- If `sp_for_switch_flag` is equal to 0, the P macroblocks in the SP slice shall be decoded using the SP decoding process for non-switching pictures as specified in subclause 8.6.1.
- Otherwise (`sp_for_switch_flag` is equal to 1), the P macroblocks in the SP slice shall be decoded using the SP and SI decoding process for switching pictures as specified in subclause 8.6.2.

slice_qs_delta specifies the value of QS_Y for all the macroblocks in SP and SI slices. The QS_Y quantisation parameter for the slice is computed as:

$$QS_Y = 26 + pic_init_qs_minus26 + slice_qs_delta \quad (7-28)$$

The value of `slice_qs_delta` shall be limited such that QS_Y is in the range of 0 to 51, inclusive. This value of QS_Y is used for the decoding of all macroblocks in SI slices with `mb_type` equal to SI and all macroblocks in SP slices with prediction mode equal to inter.

disable_deblocking_filter_idc specifies whether the operation of the deblocking filter shall be disabled across some block edges of the slice and specifies for which edges the filtering is disabled. When `disable_deblocking_filter_idc` is not present in the slice header, the value of `disable_deblocking_filter_idc` shall be inferred to be equal to 0.

The value of `disable_deblocking_filter_idc` shall be in the range of 0 to 2, inclusive.

slice_alpha_c0_offset_div2 specifies the offset used in accessing the α and t_{c0} deblocking filter tables for filtering operations controlled by the macroblocks within the slice. From this value, the offset that shall be applied when addressing these tables shall be computed as:

$$\text{FilterOffsetA} = \text{slice_alpha_c0_offset_div2} \ll 1 \quad (7-29)$$

The value of `slice_alpha_c0_offset_div2` shall be in the range of -6 to +6, inclusive. When `slice_alpha_c0_offset_div2` is not present in the slice header, the value of `slice_alpha_c0_offset_div2` shall be inferred to be equal to 0.

slice_beta_offset_div2 specifies the offset used in accessing the β deblocking filter table for filtering operations controlled by the macroblocks within the slice. From this value, the offset that is applied when addressing the β table of the deblocking filter shall be computed as:

$$\text{FilterOffsetB} = \text{slice_beta_offset_div2} \ll 1 \quad (7-30)$$

The value of `slice_beta_offset_div2` shall be in the range of -6 to +6, inclusive. When `slice_beta_offset_div2` is not present in the slice header the value of `slice_beta_offset_div2` shall be inferred to be equal to 0.

slice_group_change_cycle is used to derive the number of slice group map units in slice group 0 when `slice_group_map_type` is equal to 3, 4, or 5, as specified by

$$\text{MapUnitsInSliceGroup0} = \text{Min}(\text{slice_group_change_cycle} * \text{SliceGroupChangeRate}, \text{PicSizeInMapUnits}) \quad (7-31)$$

The value of `slice_group_change_cycle` is represented in the bitstream by the following number of bits

$$\text{Ceil}(\text{Log2}(\text{PicSizeInMapUnits} \div \text{SliceGroupChangeRate} + 1)) \quad (7-32)$$

The value of `slice_group_change_cycle` shall be in the range of 0 to $\text{Ceil}(\text{PicSizeInMapUnits} \div \text{SliceGroupChangeRate})$, inclusive.

7.4.3.1 Reference picture list reordering semantics

The syntax elements `reordering_of_pic_nums_idc`, `abs_diff_pic_num_minus1`, and `long_term_pic_num` specify the change from the initial reference picture lists to the reference picture lists to be used for decoding the slice.

ref_pic_list_reordering_flag_l0 equal to 1 specifies that the syntax element `reordering_of_pic_nums_idc` is present for specifying reference picture list 0. `ref_pic_list_reordering_flag_l0` equal to 0 specifies that this syntax element is not present.

When `ref_pic_list_reordering_flag_l0` is equal to 1, the number of times that `reordering_of_pic_nums_idc` is not equal to 3 following `ref_pic_list_reordering_flag_l0` shall not exceed `num_ref_idx_l0_active_minus1 + 1`.

When `RefPicList0[num_ref_idx_l0_active_minus1]` in the initial reference picture list produced as specified in subclause 8.2.4.2 is equal to "no reference picture", `ref_pic_list_reordering_flag_l0` shall be equal to 1 and `reordering_of_pic_nums_idc` shall not be equal to 3 until `RefPicList0[num_ref_idx_l0_active_minus1]` in the reordered list produced as specified in subclause 8.2.4.3 is not equal to "no reference picture".

ref_pic_list_reordering_flag_11 equal to 1 specifies that the syntax element **reordering_of_pic_nums_idc** is present for specifying reference picture list 1. **ref_pic_list_reordering_flag_11** equal to 0 specifies that this syntax element is not present.

When **ref_pic_list_reordering_flag_11** is equal to 1, the number of times that **reordering_of_pic_nums_idc** is not equal to 3 following **ref_pic_list_reordering_flag_11** shall not exceed **num_ref_idx_11_active_minus1** + 1.

When decoding a B slice and **RefPicList1[num_ref_idx_11_active_minus1]** in the initial reference picture list produced as specified in subclause 8.2.4.2 is equal to "no reference picture", **ref_pic_list_reordering_flag_11** shall be equal to 1 and **reordering_of_pic_nums_idc** shall not be equal to 3 until **RefPicList1[num_ref_idx_11_active_minus1]** in the reordered list produced as specified in subclause 8.2.4.3 is not equal to "no reference picture".

reordering_of_pic_nums_idc together with **abs_diff_pic_num_minus1** or **long_term_pic_num** specifies which of the reference pictures are re-mapped. The values of **reordering_of_pic_nums_idc** are specified in Table 7-7. The value of the first **reordering_of_pic_nums_idc** that follows immediately after **ref_pic_list_reordering_flag_10** or **ref_pic_list_reordering_flag_11** shall not be equal to 3.

Table 7-7 – reordering_of_pic_nums_idc operations for reordering of reference picture lists

reordering_of_pic_nums_idc	Reordering specified
0	abs_diff_pic_num_minus1 is present and corresponds to a difference to subtract from a picture number prediction value
1	abs_diff_pic_num_minus1 is present and corresponds to a difference to add to a picture number prediction value
2	long_term_pic_num is present and specifies the long-term picture number for a reference picture
3	End loop for reordering of the initial reference picture list

abs_diff_pic_num_minus1 plus 1 specifies the absolute difference between the picture number of the picture being moved to the current index in the list and the picture number prediction value. **abs_diff_pic_num_minus1** shall be in the range of 0 to **MaxPicNum** – 1. The allowed values of **abs_diff_pic_num_minus1** are further restricted as specified in subclause 8.2.4.3.1.

long_term_pic_num specifies the long-term picture number of the picture being moved to the current index in the list. When decoding a coded frame, **long_term_pic_num** shall be equal to a **LongTermPicNum** assigned to one of the reference frames or complementary reference field pairs marked as "used for long-term reference". When decoding a coded field, **long_term_pic_num** shall be equal to a **LongTermPicNum** assigned to one of the reference fields marked as "used for long-term reference".

7.4.3.2 Prediction weight table 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.

chroma_log2_weight_denom is the base 2 logarithm of the denominator for all chroma weighting factors. The value of **chroma_log2_weight_denom** shall be in the range of 0 to 7, inclusive.

luma_weight_10_flag equal to 1 specifies that weighting factors for the luma component of list 0 prediction are present. **luma_weight_10_flag** equal to 0 specifies that these weighting factors are not present.

luma_weight_10[i] is the weighting factor applied to the luma prediction value for list 0 prediction using **RefPicList0[i]**. When **luma_weight_10_flag** is equal to 1, the value of **luma_weight_10[i]** shall be in the range of –128 to 127, inclusive. When **luma_weight_10_flag** is equal to 0, **luma_weight_10[i]** shall be inferred to be equal to $2^{\text{luma_log2_weight_denom}}$ for **RefPicList0[i]**.

luma_offset_10[i] is the additive offset applied to the luma prediction value for list 0 prediction using **RefPicList0[i]**. The value of **luma_offset_10[i]** shall be in the range of –128 to 127, inclusive. When **luma_weight_10_flag** is equal to 0, **luma_offset_10[i]** shall be inferred as equal to 0 for **RefPicList0[i]**.

chroma_weight_10_flag equal to 1 specifies that weighting factors for the chroma prediction values of list 0 prediction are present. **chroma_weight_10_flag** equal to 0 specifies that these weighting factors are not present.

chroma_weight_10[i][j] is 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. When chroma_weight_10_flag is equal to 1, the value of chroma_weight_10[i][j] shall be in the range of -128 to 127, inclusive. When chroma_weight_10_flag is equal to 0, chroma_weight_10[i][j] shall be inferred to be equal to $2^{\text{chroma_log2_weight_denom}}$ for RefPicList0[i].

chroma_offset_10[i][j] is 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 value of chroma_offset_10[i][j] shall be in the range of -128 to 127, inclusive. When chroma_weight_10_flag is equal to 0, chroma_offset_10[i][j] shall be inferred to be equal to 0 for RefPicList0[i].

luma_weight_11_flag, **luma_weight_11**, **luma_offset_11**, **chroma_weight_11_flag**, **chroma_weight_11**, **chroma_offset_11** have the same semantics as luma_weight_10_flag, luma_weight_10, luma_offset_10, chroma_weight_10_flag, chroma_weight_10, chroma_offset_10, respectively, with 10, list 0, and List0 replaced by 11, list 1, and List1, respectively.

7.4.3.3 Decoded reference picture marking semantics

The syntax elements no_output_of_prior_pics_flag, long_term_reference_flag, adaptive_ref_pic_marking_mode_flag, memory_management_control_operation, difference_of_pic_nums_minus1, long_term_frame_idx, long_term_pic_num, and max_long_term_frame_idx_plus1 specify marking of the reference pictures.

The marking of a reference picture can be "unused for reference", "used for short-term reference", or "used for long-term reference", but only one among these three. When a reference 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). A reference picture that is marked as "used for short-term reference" is referred to as a short-term reference picture. A reference picture that is marked as "used for long-term reference" is referred to as a long-term reference picture.

The syntax element adaptive_ref_pic_marking_mode_flag and the content of the decoded reference picture marking syntax structure shall be identical for all coded slices of a coded picture.

The syntax category of the decoded reference picture marking syntax structure shall be inferred as follows.

- If the decoded reference picture marking syntax structure is in a slice header, the syntax category of the decoded reference picture marking syntax structure shall be inferred to be equal to 2.
- Otherwise (the decoded reference picture marking syntax structure is in a decoded reference picture marking repetition SEI message as specified in Annex D), the syntax category of the decoded reference picture marking syntax structure shall be inferred to be equal to 5.

no_output_of_prior_pics_flag specifies how the previously-decoded pictures in the decoded picture buffer are treated after decoding of an IDR picture. See Annex C. When the IDR picture is the first IDR picture in the bitstream, the value of no_output_of_prior_pics_flag has no effect on the decoding process. When the IDR picture is not the first IDR picture in the bitstream and the value of PicWidthInMbs, FrameHeightInMbs, or max_dec_frame_buffering derived from the active sequence parameter set is different from the value of PicWidthInMbs, FrameHeightInMbs, or max_dec_frame_buffering derived from the sequence parameter set active for the preceding sequence, no_output_of_prior_pics_flag equal to 1 may be inferred by the decoder, regardless of the actual value of no_output_of_prior_pics_flag.

long_term_reference_flag equal to 0 specifies that the MaxLongTermFrameIdx variable is set equal to "no long-term frame indices" and that the IDR picture is marked as "used for short-term reference". long_term_reference_flag equal to 1 specifies that the MaxLongTermFrameIdx variable is set equal to 0 and that the current IDR picture is marked "used for long-term reference" and is assigned LongTermFrameIdx equal to 0. When num_ref_frames is equal to 0, long_term_reference_flag shall be equal to 0.

adaptive_ref_pic_marking_mode_flag selects the reference picture marking mode of the currently decoded picture as specified in Table 7-8. adaptive_ref_pic_marking_mode_flag shall be equal to 1 when the number of frames, complementary field pairs, and non-paired fields that are currently marked as "used for long-term reference" is equal to Max(num_ref_frames, 1).

Table 7-8 – Interpretation of adaptive_ref_pic_marking_mode_flag

adaptive_ref_pic_marking_mode_flag	Reference picture marking mode specified
0	Sliding window reference picture marking mode: A marking mode providing a first-in first-out mechanism for short-term reference pictures.
1	Adaptive reference picture marking mode: A reference picture marking mode providing syntax elements to specify marking of reference pictures as “unused for reference” and to assign long-term frame indices.

memory_management_control_operation specifies a control operation to be applied to affect the reference picture marking. The `memory_management_control_operation` syntax element is followed by data necessary for the operation specified by the value of `memory_management_control_operation`. The values and control operations associated with `memory_management_control_operation` are specified in Table 7-9. The `memory_management_control_operation` syntax elements are processed by the decoding process in the order in which they appear in the slice header, and the semantics constraints expressed for each `memory_management_control_operation` apply at the specific position in that order at which that individual `memory_management_control_operation` is processed.

For interpretation of `memory_management_control_operation`, the term reference picture is interpreted as follows.

- If the current picture is a frame, the term reference picture refers either to a reference frame or a complementary reference field pair.
- Otherwise (the current picture is a field), the term reference picture refers either to a reference field or a field of a reference frame.

`memory_management_control_operation` shall not be equal to 1 in a slice header unless the specified reference picture is marked as "used for short-term reference" when the `memory_management_control_operation` is processed by the decoding process.

`memory_management_control_operation` shall not be equal to 2 in a slice header unless the specified long-term picture number refers to a reference picture that is marked as "used for long-term reference" when the `memory_management_control_operation` is processed by the decoding process.

`memory_management_control_operation` shall not be equal to 3 in a slice header unless the specified reference picture is marked as "used for short-term reference" when the `memory_management_control_operation` is processed by the decoding process.

`memory_management_control_operation` shall not be equal to 3 or 6 if the value of the variable `MaxLongTermFrameIdx` is equal to "no long-term frame indices" when the `memory_management_control_operation` is processed by the decoding process.

Not more than one `memory_management_control_operation` equal to 4 shall be present in a slice header.

Not more than one `memory_management_control_operation` equal to 5 shall be present in a slice header.

Not more than one `memory_management_control_operation` equal to 6 shall be present in a slice header.

`memory_management_control_operation` shall not be equal to 5 in a slice header unless no `memory_management_control_operation` in the range of 1 to 3 is present in the same decoded reference picture marking syntax structure.

A `memory_management_control_operation` equal to 5 shall not follow a `memory_management_control_operation` equal to 6 in the same slice header.

When a `memory_management_control_operation` equal to 6 is present, any `memory_management_control_operation` equal to 2, 3, or 4 that follows the `memory_management_control_operation` equal to 6 within the same slice header shall not specify the current picture to be marked as "unused for reference".

NOTE 1 – These constraints prohibit any combination of multiple `memory_management_control_operation` syntax elements that would specify the current picture to be marked as "unused for reference". However, some other combinations of `memory_management_control_operation` syntax elements are permitted that may affect the marking status of other reference pictures more than once in the same slice header. In particular, it is permitted for a `memory_management_control_operation` equal to 3 that specifies a long-term frame index to be assigned to a particular short-term reference picture to be followed in the same slice header by a `memory_management_control_operation` equal to 2, 3, 4 or 6 that specifies the same reference picture to subsequently be marked as "unused for reference".

Table 7-9 – Memory management control operation (memory_management_control_operation) values

memory_management_control_operation	Memory Management Control Operation
0	End memory_management_control_operation syntax element loop
1	Mark a short-term reference picture as “unused for reference”
2	Mark a long-term reference picture as “unused for reference”
3	Mark a short-term reference picture as "used for long-term reference" and assign a long-term frame index to it
4	Specify the maximum long-term frame index and mark all long-term reference pictures having long-term frame indices greater than the maximum value as "unused for reference"
5	Mark all reference pictures as "unused for reference" and set the MaxLongTermFrameIdx variable to "no long-term frame indices"
6	Mark the current picture as "used for long-term reference" and assign a long-term frame index to it

When decoding a field and a memory_management_control_operation command equal to 3 is present that assigns a long-term frame index to a field that is part of a short-term reference frame or part of a short-term complementary reference field pair, another memory_management_control_operation command to assign the same long-term frame index to the other field of the same frame or complementary reference field pair shall be present in the same decoded reference picture marking syntax structure.

NOTE 2 – The above requirement must be fulfilled even when the field referred to by the memory_management_control_operation equal to 3 is subsequently marked as "unused for reference" (for example when a memory_management_control_operation equal to 2 is present in the same slice header that causes the field to be marked as "unused for reference").

When the first field (in decoding order) of a complementary reference field pair includes a long_term_reference_flag equal to 1 or a memory_management_control_operation command equal to 6, the decoded reference picture marking syntax structure for the other field of the complementary reference field pair shall contain a memory_management_control_operation command equal to 6 that assigns the same long-term frame index to the other field.

NOTE 3 – The above requirement must be fulfilled even when the first field of the complementary reference field pair is subsequently marked as "unused for reference" (for example, when a memory_management_control_operation equal to 2 is present in the slice header of the second field that causes the first field to be marked as "unused for reference").

difference_of_pic_nums_minus1 is used (with memory_management_control_operation equal to 3 or 1) to assign a long-term frame index to a short-term reference picture or to mark a short-term reference picture as “unused for reference”. When the associated memory_management_control_operation is processed by the decoding process, the resulting picture number derived from difference_of_pic_nums_minus1 shall be a picture number assigned to one of the reference pictures marked as "used for reference" and not previously assigned to a long-term frame index.

The resulting picture number is constrained as follows.

- If field_pic_flag is equal to 0, the resulting picture number shall be one of the set of picture numbers assigned to reference frames or complementary reference field pairs.

NOTE 4 – When field_pic_flag is equal to 0, the resulting picture number must be a picture number assigned to a complementary reference field pair in which both fields are marked as "used for reference" or a frame in which both fields are marked as "used for reference". In particular, when field_pic_flag is equal to 0, the marking of a non-paired field or a frame in which a single field is marked as "used for reference" cannot be affected by a memory_management_control_operation equal to 1.

- Otherwise (field_pic_flag is equal to 1), the resulting picture number shall be one of the set of picture numbers assigned to reference fields.

long_term_pic_num is used (with `memory_management_control_operation` equal to 2) to mark a long-term reference picture as "unused for reference". When the associated `memory_management_control_operation` is processed by the decoding process, `long_term_pic_num` shall be equal to a long-term picture number assigned to one of the reference pictures that is currently marked as "used for long-term reference".

The resulting long-term picture number is constrained as follows.

- If `field_pic_flag` is equal to 0, the resulting long-term picture number shall be one of the set of long-term picture numbers assigned to reference frames or complementary reference field pairs.

NOTE 5 – When `field_pic_flag` is equal to 0, the resulting long-term picture number must be a long-term picture number assigned to a complementary reference field pair in which both fields are marked as "used for reference" or a frame in which both fields are marked as "used for reference". In particular, when `field_pic_flag` is equal to 0, the marking of a non-paired field or a frame in which a single field is marked as "used for reference" cannot be affected by a `memory_management_control_operation` equal to 2.

- Otherwise (`field_pic_flag` is equal to 1), the resulting long-term picture number shall be one of the set of long-term picture numbers assigned to reference fields.

long_term_frame_idx is used (with `memory_management_control_operation` equal to 3 or 6) to assign a long-term frame index to a picture. When the associated `memory_management_control_operation` is processed by the decoding process, the value of `long_term_frame_idx` shall be in the range of 0 to `MaxLongTermFrameIdx`, inclusive.

max_long_term_frame_idx_plus1 minus 1 specifies the maximum value of long-term frame index allowed for long-term reference pictures (until receipt of another value of `max_long_term_frame_idx_plus1`). The value of `max_long_term_frame_idx_plus1` shall be in the range of 0 to `num_ref_frames`, inclusive.

7.4.4 Slice data semantics

cabac_alignment_one_bit is a bit equal to 1.

mb_skip_run specifies the number of consecutive skipped macroblocks for which, when decoding a P or SP slice, `mb_type` shall be inferred to be `P_Skip` and the macroblock type is collectively referred to as a P macroblock type, or for which, when decoding a B slice, `mb_type` shall be inferred to be `B_Skip` and the macroblock type is collectively referred to as a B macroblock type. The value of `mb_skip_run` shall be in the range of 0 to `PicSizeInMbs – CurrMbAddr`, inclusive.

mb_skip_flag equal to 1 specifies that for the current macroblock, when decoding a P or SP slice, `mb_type` shall be inferred to be `P_Skip` and the macroblock type is collectively referred to as P macroblock type, or for which, when decoding a B slice, `mb_type` shall be inferred to be `B_Skip` and the macroblock type is collectively referred to as B macroblock type. `mb_skip_flag` equal to 0 specifies that the current macroblock is not skipped.

mb_field_decoding_flag equal to 0 specifies that the current macroblock pair is a frame macroblock pair. `mb_field_decoding_flag` equal to 1 specifies that the macroblock pair is a field macroblock pair. Both macroblocks of a frame macroblock pair are referred to in the text as frame macroblocks, whereas both macroblocks of a field macroblock pair are referred to in the text as field macroblocks.

When `mb_field_decoding_flag` is not present for either macroblock of a macroblock pair, the value of `mb_field_decoding_flag` is derived as follows.

- If there is a neighbouring macroblock pair immediately to the left of the current macroblock pair in the same slice, the value of `mb_field_decoding_flag` shall be inferred to be equal to the value of `mb_field_decoding_flag` for the neighbouring macroblock pair immediately to the left of the current macroblock pair,
- Otherwise, if there is no neighbouring macroblock pair immediately to the left of the current macroblock pair in the same slice and there is a neighbouring macroblock pair immediately above the current macroblock pair in the same slice, the value of `mb_field_decoding_flag` shall be inferred to be equal to the value of `mb_field_decoding_flag` for the neighbouring macroblock pair immediately above the current macroblock pair,
- Otherwise (there is no neighbouring macroblock pair either immediately to the left or immediately above the current macroblock pair in the same slice), the value of `mb_field_decoding_flag` shall be inferred to be equal to 0.

end_of_slice_flag equal to 0 specifies that another macroblock is following in the slice. `end_of_slice_flag` equal to 1 specifies the end of the slice and that no further macroblock follows.

The function `NextMbAddress()` used in the slice data syntax table is specified in subclause 8.2.2.

7.4.5 Macroblock layer semantics

mb_type specifies the macroblock type. The semantics of `mb_type` depend on the slice type.

Tables and semantics are specified for the various macroblock types for I, SI, P, SP, and B slices. Each table presents the value of `mb_type`, the name of `mb_type`, the number of macroblock partitions used (given by the `NumMbPart(mb_type)` function), the prediction mode of the macroblock (when it is not partitioned) or the first partition (given by the `MbPartPredMode(mb_type, 0)` function) and the prediction mode of the second partition (given by the `MbPartPredMode(mb_type, 1)` function). When a value is not applicable it is designated by “na”. In the text, the value of `mb_type` may be referred to as the macroblock type and a value X of `MbPartPredMode()` may be referred to in the text by “X macroblock (partition) prediction mode” or as “X prediction macroblocks”.

Table 7-10 shows the allowed collective macroblock types for each `slice_type`.

NOTE 1 – There are some macroblock types with `Pred_L0` prediction mode that are classified as B macroblock types.

Table 7-10 – Allowed collective macroblock types for `slice_type`

slice_type	allowed collective macroblock types
I (slice)	I (see Table 7-11) (macroblock types)
P (slice)	P (see Table 7-13) and I (see Table 7-11) (macroblock types)
B (slice)	B (see Table 7-14) and I (see Table 7-11) (macroblock types)
SI (slice)	SI (see Table 7-12) and I (see Table 7-11) (macroblock types)
SP (slice)	P (see Table 7-13) and I (see Table 7-11) (macroblock types)

transform_size_8x8_flag equal to 1 specifies that for the current macroblock the transform coefficient decoding process and picture construction process prior to deblocking filter process for residual 8x8 blocks shall be invoked for luma samples. **transform_size_8x8_flag** equal to 0 specifies that for the current macroblock the transform coefficient decoding process and picture construction process prior to deblocking filter process for residual 4x4 blocks shall be invoked for luma samples. When **transform_size_8x8_flag** is not present in the bitstream, it shall be inferred to be equal to 0.

NOTE 2 – When the current macroblock prediction mode `MbPartPredMode(mb_type, 0)` is equal to `Intra_16x16`, **transform_size_8x8_flag** is not present in the bitstream and then inferred to be equal to 0.

When `sub_mb_type[mbPartIdx]` (see subclause 7.4.5.2) is present in the bitstream for all 8x8 blocks indexed by `mbPartIdx = 0..3`, the variable `noSubMbPartSizeLessThan8x8Flag` indicates whether for each of the four 8x8 blocks the corresponding `SubMbPartWidth(sub_mb_type[mbPartIdx])` and `SubMbPartHeight(sub_mb_type[mbPartIdx])` are both equal to 8.

NOTE 3 – When `noSubMbPartSizeLessThan8x8Flag` is equal to 0 and the current macroblock type is not equal to `I_NxN`, **transform_size_8x8_flag** is not present in the bitstream and then inferred to be equal to 0.

Macroblock types that may be collectively referred to as I macroblock types are specified in Table 7-11.

The macroblock types for I slices are all I macroblock types.

Table 7-11 – Macroblock types for I slices

mb_type	Name of mb_type	transform_size_8x8_flag	MbPartPredMode (mb_type, 0)	Intra16x16PredMode	CodedBlockPatternChroma	CodedBlockPatternLuma
0	I_NxN	0	Intra_4x4	na	Equation 7-33	Equation 7-33
0	I_NxN	1	Intra_8x8	na	Equation 7-33	Equation 7-33
1	I_16x16_0_0_0	na	Intra_16x16	0	0	0
2	I_16x16_1_0_0	na	Intra_16x16	1	0	0
3	I_16x16_2_0_0	na	Intra_16x16	2	0	0
4	I_16x16_3_0_0	na	Intra_16x16	3	0	0
5	I_16x16_0_1_0	na	Intra_16x16	0	1	0
6	I_16x16_1_1_0	na	Intra_16x16	1	1	0
7	I_16x16_2_1_0	na	Intra_16x16	2	1	0
8	I_16x16_3_1_0	na	Intra_16x16	3	1	0
9	I_16x16_0_2_0	na	Intra_16x16	0	2	0
10	I_16x16_1_2_0	na	Intra_16x16	1	2	0
11	I_16x16_2_2_0	na	Intra_16x16	2	2	0
12	I_16x16_3_2_0	na	Intra_16x16	3	2	0
13	I_16x16_0_0_1	na	Intra_16x16	0	0	15
14	I_16x16_1_0_1	na	Intra_16x16	1	0	15
15	I_16x16_2_0_1	na	Intra_16x16	2	0	15
16	I_16x16_3_0_1	na	Intra_16x16	3	0	15
17	I_16x16_0_1_1	na	Intra_16x16	0	1	15
18	I_16x16_1_1_1	na	Intra_16x16	1	1	15
19	I_16x16_2_1_1	na	Intra_16x16	2	1	15
20	I_16x16_3_1_1	na	Intra_16x16	3	1	15
21	I_16x16_0_2_1	na	Intra_16x16	0	2	15
22	I_16x16_1_2_1	na	Intra_16x16	1	2	15
23	I_16x16_2_2_1	na	Intra_16x16	2	2	15
24	I_16x16_3_2_1	na	Intra_16x16	3	2	15
25	I_PCM	na	na	na	na	na

The following semantics are assigned to the macroblock types in Table 7-11.

I_{NxN}: A mnemonic name for mb_type equal to 0 with MbPartPredMode(mb_type, 0) equal to Intra_4x4 or Intra_8x8.

I_{16x16_0_0_0}, I_{16x16_1_0_0}, I_{16x16_2_0_0}, I_{16x16_3_0_0}, I_{16x16_0_1_0}, I_{16x16_1_1_0}, I_{16x16_2_1_0}, I_{16x16_3_1_0}, I_{16x16_0_2_0}, I_{16x16_1_2_0}, I_{16x16_2_2_0}, I_{16x16_3_2_0}, I_{16x16_0_0_1}, I_{16x16_1_0_1}, I_{16x16_2_0_1}, I_{16x16_3_0_1}, I_{16x16_0_1_1}, I_{16x16_1_1_1}, I_{16x16_2_1_1}, I_{16x16_3_1_1}, I_{16x16_0_2_1}, I_{16x16_1_2_1}, I_{16x16_2_2_1}, I_{16x16_3_2_1}: the macroblock is coded as an Intra_16x16 prediction mode macroblock.

To each Intra_16x16 prediction macroblock, an Intra16x16PredMode is assigned, which specifies the Intra_16x16 prediction mode. CodedBlockPatternChroma contains the coded block pattern value for chroma as specified in Table 7-15. When chroma_format_idc is equal to 0, CodedBlockPatternChroma shall be equal to 0. CodedBlockPatternLuma specifies whether, for the luma component, non-zero AC transform coefficient levels are present. CodedBlockPatternLuma equal to 0 specifies that all AC transform coefficient levels in the luma component of the macroblock are equal to 0. CodedBlockPatternLuma equal to 15 specifies that at least one of the AC transform coefficient levels in the luma component of the macroblock is non-zero, requiring scanning of AC transform coefficient levels for all 16 of the 4x4 blocks in the 16x16 block.

Intra_4x4 specifies the macroblock prediction mode and specifies that the Intra_4x4 prediction process is invoked as specified in subclause 8.3.1. Intra_4x4 is an Intra macroblock prediction mode.

Intra_8x8 specifies the macroblock prediction mode and specifies that the Intra_8x8 prediction process is invoked as specified in subclause 8.3.2. Intra_8x8 is an Intra macroblock prediction mode.

Intra_16x16 specifies the macroblock prediction mode and specifies that the Intra_16x16 prediction process is invoked as specified in subclause 8.3.3. Intra_16x16 is an Intra macroblock prediction mode.

For a macroblock coded with mb_type equal to I_PCM, the Intra macroblock prediction mode shall be inferred.

A macroblock type that may be referred to as SI macroblock type is specified in Table 7-12.

The macroblock types for SI slices are specified in Tables 7-12 and 7-11. The mb_type value 0 is specified in Table 7-12 and the mb_type values 1 to 26 are specified in Table 7-11, indexed by subtracting 1 from the value of mb_type.

Table 7-12 – Macroblock type with value 0 for SI slices

mb_type	Name of mb_type	MbPartPredMode (mb_type, 0)	Intra16x16PredMode	CodedBlockPatternChroma	CodedBlockPatternLuma
0	SI	Intra_4x4	na	Equation 7-33	Equation 7-33

The following semantics are assigned to the macroblock type in Table 7-12. The SI macroblock is coded as Intra_4x4 prediction macroblock.

Macroblock types that may be collectively referred to as P macroblock types are specified in Table 7-13.

The macroblock types for P and SP slices are specified in Tables 7-13 and 7-11. mb_type values 0 to 4 are specified in Table 7-13 and mb_type values 5 to 30 are specified in Table 7-11, indexed by subtracting 5 from the value of mb_type.

Table 7-13 – Macroblock type values 0 to 4 for P and SP slices

mb_type	Name of mb_type	NumMbPart (mb_type)	MbPartPredMode (mb_type, 0)	MbPartPredMode (mb_type, 1)	MbPartWidth (mb_type)	MbPartHeight (mb_type)
0	P_L0_16x16	1	Pred_L0	na	16	16
1	P_L0_L0_16x8	2	Pred_L0	Pred_L0	16	8
2	P_L0_L0_8x16	2	Pred_L0	Pred_L0	8	16
3	P_8x8	4	na	na	8	8
4	P_8x8ref0	4	na	na	8	8
inferred	P_Skip	1	Pred_L0	na	16	16

The following semantics are assigned to the macroblock types in Table 7-13.

- P_L0_16x16: the samples of the macroblock are predicted with one luma macroblock partition of size 16x16 luma samples and associated chroma samples.
- P_L0_L0_MxN, with MxN being replaced by 16x8 or 8x16: the samples of the macroblock are predicted using two luma partitions of size MxN equal to 16x8, or two luma partitions of size MxN equal to 8x16, and associated chroma samples, respectively.
- P_8x8: for each sub-macroblock an additional syntax element (sub_mb_type) is present in the bitstream that specifies the type of the corresponding sub-macroblock (see subclause 7.4.5.2).
- P_8x8ref0: has the same semantics as P_8x8 but no syntax element for the reference index (ref_idx_l0) is present in the bitstream and ref_idx_l0[mbPartIdx] shall be inferred to be equal to 0 for all sub-macroblocks of the macroblock (with indices mbPartIdx equal to 0..3).
- P_Skip: no further data is present for the macroblock in the bitstream.

The following semantics are assigned to the macroblock prediction modes (MbPartPredMode()) in Table 7-13.

- Pred_L0: specifies that the inter prediction process is invoked using list 0 prediction. Pred_L0 is an Inter macroblock prediction mode.

Macroblock types that may be collectively referred to as B macroblock types are specified in Table 7-14.

The macroblock types for B slices are specified in Tables 7-14 and 7-11. The mb_type values 0 to 22 are specified in Table 7-14 and the mb_type values 23 to 48 are specified in Table 7-11, indexed by subtracting 23 from the value of mb_type.

Table 7-14 – Macroblock type values 0 to 22 for B slices

mb_type	Name of mb_type	NumMbPart (mb_type)	MbPartPredMode (mb_type, 0)	MbPartPredMode (mb_type, 1)	MbPartWidth (mb_type)	MbPartHeight (mb_type)
0	B_Direct_16x16	na	Direct	na	8	8
1	B_L0_16x16	1	Pred_L0	na	16	16
2	B_L1_16x16	1	Pred_L1	na	16	16
3	B_Bi_16x16	1	BiPred	na	16	16
4	B_L0_L0_16x8	2	Pred_L0	Pred_L0	16	8
5	B_L0_L0_8x16	2	Pred_L0	Pred_L0	8	16
6	B_L1_L1_16x8	2	Pred_L1	Pred_L1	16	8
7	B_L1_L1_8x16	2	Pred_L1	Pred_L1	8	16
8	B_L0_L1_16x8	2	Pred_L0	Pred_L1	16	8
9	B_L0_L1_8x16	2	Pred_L0	Pred_L1	8	16
10	B_L1_L0_16x8	2	Pred_L1	Pred_L0	16	8
11	B_L1_L0_8x16	2	Pred_L1	Pred_L0	8	16
12	B_L0_Bi_16x8	2	Pred_L0	BiPred	16	8
13	B_L0_Bi_8x16	2	Pred_L0	BiPred	8	16
14	B_L1_Bi_16x8	2	Pred_L1	BiPred	16	8
15	B_L1_Bi_8x16	2	Pred_L1	BiPred	8	16
16	B_Bi_L0_16x8	2	BiPred	Pred_L0	16	8
17	B_Bi_L0_8x16	2	BiPred	Pred_L0	8	16
18	B_Bi_L1_16x8	2	BiPred	Pred_L1	16	8
19	B_Bi_L1_8x16	2	BiPred	Pred_L1	8	16
20	B_Bi_Bi_16x8	2	BiPred	BiPred	16	8
21	B_Bi_Bi_8x16	2	BiPred	BiPred	8	16
22	B_8x8	4	na	na	8	8
inferred	B_Skip	na	Direct	na	8	8

The following semantics are assigned to the macroblock types in Table 7-14:

- B_Direct_16x16: no motion vector differences or reference indices are present for the macroblock in the bitstream. The functions MbPartWidth(B_Direct_16x16), and MbPartHeight(B_Direct_16x16) are used in the derivation process for motion vectors and reference frame indices in subclause 8.4.1 for direct mode prediction.
- B_X_16x16 with X being replaced by L0, L1, or Bi: the samples of the macroblock are predicted with one luma macroblock partition of size 16x16 luma samples and associated chroma samples. For a macroblock with type B_X_16x16 with X being replaced by either L0 or L1, one motion vector difference and one reference index is

present in the bitstream for the macroblock. For a macroblock with type $B_X_16 \times 16$ with X being replaced by B_i , two motion vector differences and two reference indices are present in the bitstream for the macroblock.

- $B_X0_X1_M \times N$, with $X0, X1$ referring to the first and second macroblock partition and being replaced by $L0, L1$, or B_i , and $M \times N$ being replaced by 16×8 or 8×16 : the samples of the macroblock are predicted using two luma partitions of size $M \times N$ equal to 16×8 , or two luma partitions of size $M \times N$ equal to 8×16 , and associated chroma samples, respectively. For a macroblock partition $X0$ or $X1$ with $X0$ or $X1$ being replaced by either $L0$ or $L1$, one motion vector difference and one reference index is present in the bitstream. For a macroblock partition $X0$ or $X1$ with $X0$ or $X1$ being replaced by B_i , two motion vector differences and two reference indices are present in the bitstream for the macroblock partition.
- $B_8 \times 8$: for each sub-macroblock an additional syntax element (`sub_mb_type`) is present in the bitstream that specifies the type of the corresponding sub-macroblock (see subclause 7.4.5.2).
- B_Skip : no further data is present for the macroblock in the bitstream. The functions `MbPartWidth(B_Skip)`, and `MbPartHeight(B_Skip)` are used in the derivation process for motion vectors and reference frame indices in subclause 8.4.1 for direct mode prediction.

The following semantics are assigned to the macroblock prediction modes (`MbPartPredMode()`) in Table 7-14.

- **Direct**: no motion vector differences or reference indices are present for the macroblock (in case of B_Skip or $B_Direct_16 \times 16$) in the bitstream. Direct is an Inter macroblock prediction mode.
- **Pred_L0**: see semantics for Table 7-13.
- **Pred_L1**: specifies that the Inter prediction process is invoked using list 1 prediction. **Pred_L1** is an Inter macroblock prediction mode.
- **BiPred**: specifies that the Inter prediction process is invoked using list 0 and list 1 prediction. **BiPred** is an Inter macroblock prediction mode.

pcm_alignment_zero_bit is a bit equal to 0.

pcm_sample_luma[i] is a sample value. The first `pcm_sample_luma[i]` values represent luma sample values in the raster scan within the macroblock. The number of bits used to represent each of these samples is $BitDepth_Y$. When `profile_idc` is not equal to 100, 110, 122, or 144, `pcm_sample_luma[i]` shall not be equal to 0.

pcm_sample_chroma[i] is a sample value. The first $MbWidthC * MbHeightC$ `pcm_sample_chroma[i]` values represent C_b sample values in the raster scan within the macroblock and the remaining $MbWidthC * MbHeightC$ `pcm_sample_chroma[i]` values represent C_r sample values in the raster scan within the macroblock. The number of bits used to represent each of these samples is $BitDepth_C$. When `profile_idc` is not equal to 100, 110, 122, or 144, `pcm_sample_chroma[i]` shall not be equal to 0.

coded_block_pattern specifies which of the four 8×8 luma blocks and associated chroma blocks of a macroblock may contain non-zero transform coefficient levels. For macroblocks with prediction mode not equal to $Intra_16 \times 16$, `coded_block_pattern` is present in the bitstream and the variables `CodedBlockPatternLuma` and `CodedBlockPatternChroma` are derived as follows.

$$\begin{aligned} CodedBlockPatternLuma &= coded_block_pattern \% 16 \\ CodedBlockPatternChroma &= coded_block_pattern / 16 \end{aligned} \quad (7-33)$$

When `coded_block_pattern` is present, `CodedBlockPatternLuma` specifies, for each of the four 8×8 luma blocks of the macroblock, one of the following cases.

- All transform coefficient levels of the four 4×4 luma blocks in the 8×8 luma block are equal to zero
- One or more transform coefficient levels of one or more of the 4×4 luma blocks in the 8×8 luma block shall be non-zero valued.

The meaning of `CodedBlockPatternChroma` is specified in Table 7-15.

Table 7-15 – Specification of CodedBlockPatternChroma values

CodedBlockPatternChroma	Description
0	All chroma transform coefficient levels are equal to 0.
1	One or more chroma DC transform coefficient levels shall be non-zero valued. All chroma AC transform coefficient levels are equal to 0.
2	Zero or more chroma DC transform coefficient levels are non-zero valued. One or more chroma AC transform coefficient levels shall be non-zero valued.

mb_qp_delta can change the value of QP_Y in the macroblock layer. The decoded value of **mb_qp_delta** shall be in the range of $-(26 + QpBdOffset_Y / 2)$ to $+(25 + QpBdOffset_Y / 2)$, inclusive. **mb_qp_delta** shall be inferred to be equal to 0 when it is not present for any macroblock (including P_Skip and B_Skip macroblock types).

The value of QP_Y is derived as

$$QP_Y = ((QP_{Y,PREV} + mb_qp_delta + 52 + 2 * QpBdOffset_Y) \% (52 + QpBdOffset_Y)) - QpBdOffset_Y \quad (7-34)$$

where $QP_{Y,PREV}$ is the luma quantisation parameter, QP_Y , of the previous macroblock in decoding order in the current slice. For the first macroblock in the slice $QP_{Y,PREV}$ is initially set equal to $SliceQP_Y$ derived in Equation 7-27 at the start of each slice.

The value of QP'_Y is derived as

$$QP'_Y = QP_Y + QpBdOffset_Y \quad (7-35)$$

7.4.5.1 Macroblock prediction semantics

All samples of the macroblock are predicted. The prediction modes are derived using the following syntax elements.

prev_intra4x4_pred_mode_flag[luma4x4BlkIdx] and **rem_intra4x4_pred_mode**[luma4x4BlkIdx] specify the Intra_4x4 prediction of the 4x4 luma block with index luma4x4BlkIdx = 0..15.

prev_intra8x8_pred_mode_flag[luma8x8BlkIdx] and **rem_intra8x8_pred_mode**[luma8x8BlkIdx] specify the Intra_8x8 prediction of the 8x8 luma block with index luma8x8BlkIdx = 0..3.

intra_chroma_pred_mode specifies the type of spatial prediction used for chroma in macroblocks using Intra_4x4 or Intra_16x16 prediction, as shown in Table 7-16. The value of **intra_chroma_pred_mode** shall be in the range of 0 to 3, inclusive.

Table 7-16 – Relationship between intra_chroma_pred_mode and spatial prediction modes

intra_chroma_pred_mode	Intra Chroma Prediction Mode
0	DC
1	Horizontal
2	Vertical
3	Plane

ref_idx_10[mbPartIdx] when present, specifies the index in reference picture list 0 of the reference picture to be used for prediction.

The range of **ref_idx_10**[mbPartIdx], the index in list 0 of the reference picture, and, if applicable, the parity of the field within the reference picture used for prediction are specified as follows.

- If MbaffFrameFlag is equal to 0 or mb_field_decoding_flag is equal to 0, the value of **ref_idx_10**[mbPartIdx] shall be in the range of 0 to num_ref_idx_10_active_minus1, inclusive.

- Otherwise (MbaffFrameFlag is equal to 1 and mb_field_decoding_flag is equal to 1), the value of ref_idx_10[mbPartIdx] shall be in the range of 0 to 2 * num_ref_idx_10_active_minus1 + 1, inclusive.

When only one reference picture is used for inter prediction, the values of ref_idx_10[mbPartIdx] shall be inferred to be equal to 0.

ref_idx_11[mbPartIdx] has the same semantics as ref_idx_10, with l0 and list 0 replaced by l1 and list 1, respectively.

mvd_10[mbPartIdx][0][compIdx] specifies the difference between a vector component to be used and its prediction. The index mbPartIdx specifies to which macroblock partition mvd_10 is assigned. The partitioning of the macroblock is specified by mb_type. The horizontal motion vector component difference is decoded first in decoding order and is assigned CompIdx = 0. The vertical motion vector component is decoded second in decoding order and is assigned CompIdx = 1. The range of the components of mvd_10[mbPartIdx][0][compIdx] is specified by constraints on the motion vector variable values derived from it as specified in Annex A.

mvd_11[mbPartIdx][0][compIdx] has the same semantics as mvd_10, with l0 and L0 replaced by l1 and L1, respectively.

7.4.5.2 Sub-macroblock prediction semantics

sub_mb_type[mbPartIdx] specifies the sub-macroblock types.

Tables and semantics are specified for the various sub-macroblock types for P, and B macroblock types. Each table presents the value of sub_mb_type, the name of sub_mb_type, the number of sub-macroblock partitions used (given by the NumSubMbPart(sub_mb_type) function), and the prediction mode of the sub-macroblock (given by the SubMbPredMode(sub_mb_type) function). In the text, the value of sub_mb_type may be referred to by “sub-macroblock type”. In the text, the value of SubMbPredMode() may be referred to by “sub-macroblock prediction mode”.

The interpretation of sub_mb_type[mbPartIdx] for P macroblock types is specified in Table 7-17, where the row for “inferred” specifies values inferred when sub_mb_type[mbPartIdx] is not present.

Table 7-17 – Sub-macroblock types in P macroblocks

sub_mb_type[mbPartIdx]	Name of sub_mb_type[mbPartIdx]	NumSubMbPart (sub_mb_type[mbPartIdx])	SubMbPredMode (sub_mb_type[mbPartIdx])	SubMbPartWidth (sub_mb_type[mbPartIdx])	SubMbPartHeight (sub_mb_type[mbPartIdx])
inferred	na	na	na	na	na
0	P_L0_8x8	1	Pred_L0	8	8
1	P_L0_8x4	2	Pred_L0	8	4
2	P_L0_4x8	2	Pred_L0	4	8
3	P_L0_4x4	4	Pred_L0	4	4

The following semantics are assigned to the sub-macroblock types in Table 7-17.

- P_L0_MxN, with MxN being replaced by 8x8, 8x4, 4x8, or 4x4: the samples of the sub-macroblock are predicted using one luma partition of size MxN equal to 8x8, two luma partitions of size MxN equal to 8x4, or two luma partitions of size MxN equal to 4x8, or four luma partitions of size MxN equal to 4x4, and associated chroma samples, respectively.

The following semantics are assigned to the sub-macroblock prediction modes (SubMbPredMode()) in Table 7-17.

- Pred_L0: see semantics for Table 7-13.

The interpretation of `sub_mb_type[mbPartIdx]` for B macroblock types is specified in Table 7-18, where the row for "inferred" specifies values inferred when `sub_mb_type[mbPartIdx]` is not present, and the inferred value "mb_type" specifies that the name of `sub_mb_type[mbPartIdx]` is the same as the name of `mb_type` for this case.

Table 7-18 – Sub-macroblock types in B macroblocks

<code>sub_mb_type[mbPartIdx]</code>	Name of <code>sub_mb_type[mbPartIdx]</code>	NumSubMbPart (<code>sub_mb_type[mbPartIdx]</code>)	SubMbPredMode (<code>sub_mb_type[mbPartIdx]</code>)	SubMbPartWidth (<code>sub_mb_type[mbPartIdx]</code>)	SubMbPartHeight (<code>sub_mb_type[mbPartIdx]</code>)
inferred	<code>mb_type</code>	4	Direct	4	4
0	<code>B_Direct_8x8</code>	4	Direct	4	4
1	<code>B_L0_8x8</code>	1	Pred_L0	8	8
2	<code>B_L1_8x8</code>	1	Pred_L1	8	8
3	<code>B_Bi_8x8</code>	1	BiPred	8	8
4	<code>B_L0_8x4</code>	2	Pred_L0	8	4
5	<code>B_L0_4x8</code>	2	Pred_L0	4	8
6	<code>B_L1_8x4</code>	2	Pred_L1	8	4
7	<code>B_L1_4x8</code>	2	Pred_L1	4	8
8	<code>B_Bi_8x4</code>	2	BiPred	8	4
9	<code>B_Bi_4x8</code>	2	BiPred	4	8
10	<code>B_L0_4x4</code>	4	Pred_L0	4	4
11	<code>B_L1_4x4</code>	4	Pred_L1	4	4
12	<code>B_Bi_4x4</code>	4	BiPred	4	4

The following semantics are assigned to the sub-macroblock types in Table 7-18:

- `B_Skip` and `B_Direct_16x16`: no motion vector differences or reference indices are present for the sub-macroblock in the bitstream. The functions `SubMbPartWidth()` and `SubMbPartHeight()` are used in the derivation process for motion vectors and reference frame indices in subclause 8.4.1 for direct mode prediction.
- `B_Direct_8x8`: no motion vector differences or reference indices are present for the sub-macroblock in the bitstream. The functions `SubMbPartWidth(B_Direct_8x8)` and `SubMbPartHeight(B_Direct_8x8)` are used in the derivation process for motion vectors and reference frame indices in subclause 8.4.1 for direct mode prediction.
- `B_X_MxN`, with X being replaced by L0, L1, or Bi, and MxN being replaced by 8x8, 8x4, 4x8 or 4x4: the samples of the sub-macroblock are predicted using one luma partition of size MxN equal to 8x8, or the samples of the sub-macroblock are predicted using two luma partitions of size MxN equal to 8x4, or the samples of the sub-macroblock are predicted using two luma partitions of size MxN equal to 4x8, or the samples of the sub-macroblock are predicted using four luma partitions of size MxN equal to 4x4, and associated chroma samples, respectively. All sub-macroblock partitions share the same reference index. For an MxN sub-macroblock partition in a sub-macroblock with `sub_mb_type` being `B_X_MxN` with X being replaced by either L0 or L1, one motion vector difference is present in the bitstream. For an MxN sub-macroblock partition in a sub-macroblock with `sub_mb_type` being `B_Bi_MxN`, two motion vector difference are present in the bitstream.

The following semantics are assigned to the sub-macroblock prediction modes (SubMbPredMode()) in Table 7-18.

- Direct: see semantics for Table 7-14.
- Pred_L0: see semantics for Table 7-13.
- Pred_L1: see semantics for Table 7-14.
- BiPred: see semantics for Table 7-14.

ref_idx_10[mbPartIdx] has the same semantics as ref_idx_10 in subclause 7.4.5.1.

ref_idx_11[mbPartIdx] has the same semantics as ref_idx_11 in subclause 7.4.5.1.

mvd_10[mbPartIdx][subMbPartIdx][compIdx] has the same semantics as mvd_10 in subclause 7.4.5.1, except that it is applied to the sub-macroblock partition index with subMbPartIdx. The indices mbPartIdx and subMbPartIdx specify to which macroblock partition and sub-macroblock partition mvd_10 is assigned.

mvd_11[mbPartIdx][subMbPartIdx][compIdx] has the same semantics as mvd_11 in subclause 7.4.5.1.

7.4.5.3 Residual data semantics

The syntax structure residual_block(), which is used for parsing the transform coefficient levels, is assigned as follows.

- If entropy_coding_mode_flag is equal to 0, residual_block is set equal to residual_block_cavlc, which is used for parsing the syntax elements for transform coefficient levels.
- Otherwise (entropy_coding_mode_flag is equal to 1), residual_block is set equal to residual_block_cabac, which is used for parsing the syntax elements for transform coefficient levels.

Depending on mb_type, luma or chroma, and chroma format, the syntax structure residual_block(coeffLevel, maxNumCoeff) is used with the arguments coeffLevel, which is a list containing the maxNumCoeff transform coefficient levels that are parsed in residual_block() and maxNumCoeff as follows.

- Depending on MbPartPredMode(mb_type, 0), the following applies.
 - If MbPartPredMode(mb_type, 0) is equal to Intra_16x16, the transform coefficient levels are parsed into the list Intra16x16DCLevel and into the 16 lists Intra16x16ACLevel[i]. Intra16x16DCLevel contains the 16 transform coefficient levels of the DC transform coefficient levels for each 4x4 luma block. For each of the 16 4x4 luma blocks indexed by $i = 0..15$, the 15 AC transform coefficients levels of the i -th block are parsed into the i -th list Intra16x16ACLevel[i].
 - Otherwise (MbPartPredMode(mb_type, 0) is not equal to Intra_16x16), the following applies.
 - If transform_size_8x8_flag is equal to 0, for each of the 16 4x4 luma blocks indexed by $i = 0..15$, the 16 transform coefficient levels of the i -th block are parsed into the i -th list LumaLevel[i].
 - Otherwise (transform_size_8x8_flag is equal to 1), for each of the 4 8x8 luma blocks indexed by $i8x8 = 0..3$, the following applies.
 - If entropy_coding_mode_flag is equal to 0, first for each of the 4 4x4 luma blocks indexed by $i4x4 = 0..3$, the 16 transform coefficient levels of the $i4x4$ -th block are parsed into the $(i8x8 * 4 + i4x4)$ -th list LumaLevel[$i8x8 * 4 + i4x4$]. Then, the 64 transform coefficient levels of the $i8x8$ -th 8x8 luma block which are indexed by $4 * i + i4x4$, where $i = 0..15$ and $i4x4 = 0..3$, are derived as $LumaLevel8x8[i8x8][4 * i + i4x4] = LumaLevel[i8x8 * 4 + i4x4][i]$.
NOTE – The 4x4 luma blocks with $luma4x4BlkIdx = i8x8 * 4 + i4x4$ containing every fourth transform coefficient level of the corresponding $i8x8$ -th 8x8 luma block with offset $i4x4$ are assumed to represent spatial locations given by the inverse 4x4 luma block scanning process in subclause 6.4.3.
 - Otherwise (entropy_coding_mode_flag is equal to 1), the 64 transform coefficient levels of the $i8x8$ -th block are parsed into the $i8x8$ -th list LumaLevel8x8[$i8x8$].
- For each chroma component, indexed by $iCbCr = 0..1$, the DC transform coefficient levels of the $4 * NumC8x8$ 4x4 chroma blocks are parsed into the $iCbCr$ -th list ChromaDCLevel[$iCbCr$].
- For each of the 4x4 chroma blocks, indexed by $i4x4 = 0..3$ and $i8x8 = 0..NumC8x8 - 1$, of each chroma component, indexed by $iCbCr = 0..1$, the 15 AC transform coefficient levels are parsed into the $(i8x8*4 + i4x4)$ -th list of the $iCbCr$ -th chroma component ChromaACLevel[$iCbCr$][$i8x8*4 + i4x4$].

7.4.5.3.1 Residual block CAVLC semantics

The function `TotalCoeff(coeff_token)` that is used in subclause 7.3.5.3.1 returns the number of non-zero transform coefficient levels derived from `coeff_token`.

The function `TrailingOnes(coeff_token)` that is used in subclause 7.3.5.3.1 returns the trailing ones derived from `coeff_token`.

coeff_token specifies the total number of non-zero transform coefficient levels and the number of trailing one transform coefficient levels in a transform coefficient level scan. A trailing one transform coefficient level is one of up to three consecutive non-zero transform coefficient levels having an absolute value equal to 1 at the end of a scan of non-zero transform coefficient levels. The range of `coeff_token` is specified in subclause 9.2.1.

trailing_ones_sign_flag specifies the sign of a trailing one transform coefficient level as follows.

- If `trailing_ones_sign_flag` is equal to 0, the corresponding transform coefficient level is decoded as +1.
- Otherwise (`trailing_ones_sign_flag` equal to 1), the corresponding transform coefficient level is decoded as -1.

level_prefix and **level_suffix** specify the value of a non-zero transform coefficient level. The range of `level_prefix` and `level_suffix` is specified in subclause 9.2.2.

total_zeros specifies the total number of zero-valued transform coefficient levels that are located before the position of the last non-zero transform coefficient level in a scan of transform coefficient levels. The range of `total_zeros` is specified in subclause 9.2.3.

run_before specifies the number of consecutive transform coefficient levels in the scan with zero value before a non-zero valued transform coefficient level. The range of `run_before` is specified in subclause 9.2.3.

`coeffLevel` contains `maxNumCoeff` transform coefficient levels for the current list of transform coefficient levels.

7.4.5.3.2 Residual block CABAC semantics

coded_block_flag specifies whether the block contains non-zero transform coefficient levels as follows.

- If `coded_block_flag` is equal to 0, the block contains no non-zero transform coefficient levels.
- Otherwise (`coded_block_flag` is equal to 1), the block contains at least one non-zero transform coefficient level.

significant_coeff_flag[i] specifies whether the transform coefficient level at scanning position `i` is non-zero as follows.

- If `significant_coeff_flag[i]` is equal to 0, the transform coefficient level at scanning position `i` is set equal to 0;
- Otherwise (`significant_coeff_flag[i]` is equal to 1), the transform coefficient level at scanning position `i` has a non-zero value.

last_significant_coeff_flag[i] specifies for the scanning position `i` whether there are non-zero transform coefficient levels for subsequent scanning positions `i + 1` to `maxNumCoeff - 1` as follows.

- If `last_significant_coeff_flag[i]` is equal to 1, all following transform coefficient levels (in scanning order) of the block have value equal to 0.
- Otherwise (`last_significant_coeff_flag[i]` is equal to 0), there are further non-zero transform coefficient levels along the scanning path.

coeff_abs_level_minus1[i] is the absolute value of a transform coefficient level minus 1. The value of `coeff_abs_level_minus1` is constrained by the limits in subclause 8.5.

coeff_sign_flag[i] specifies the sign of a transform coefficient level as follows.

- If `coeff_sign_flag` is equal to 0, the corresponding transform coefficient level has a positive value.
- Otherwise (`coeff_sign_flag` is equal to 1), the corresponding transform coefficient level has a negative value.

`coeffLevel` contains `maxNumCoeff` transform coefficient levels for the current list of transform coefficient levels.

8 Decoding process

Outputs of this process are decoded samples of the current picture (sometimes referred to by the variable `CurrPic`).

This clause describes the decoding process, given syntax elements and upper-case variables from clause 7.

The decoding process is specified such that all decoders shall produce numerically identical results. Any decoding process that produces identical results to the process described here conforms to the decoding process requirements of this Recommendation | International Standard.

Each picture referred to in this clause is a primary picture. Each slice referred to in this clause is a slice of a primary picture. Each slice data partition referred to in this clause is a slice data partition of a primary picture.

An overview of the decoding process is given as follows.

- The decoding of NAL units is specified in subclause 8.1.
- The processes in subclause 8.2 specify decoding processes using syntax elements in the slice layer and above.
 - Variables and functions relating to picture order count are derived in subclause 8.2.1. (only needed to be invoked for one slice of a picture)
 - Variables and functions relating to the macroblock to slice group map are derived in subclause 8.2.2. (only needed to be invoked for one slice of a picture)
 - The method of combining the various partitions when slice data partitioning is used is described in subclause 8.2.3.
 - When the `frame_num` of the current picture is not equal to `PrevRefFrameNum` and is not equal to $(\text{PrevRefFrameNum} + 1) \% \text{MaxFrameNum}$, the decoding process for gaps in `frame_num` is performed according to subclause 8.2.5.2 prior to the decoding of any slices of the current picture.
 - At the beginning of the decoding process for each P, SP, or B slice, the decoding process for reference picture lists construction specified in 8.2.4 performed for derivation of reference picture list 0 (`RefPicList0`), and when decoding a B slice, reference picture list 1 (`RefPicList1`).
 - When the current picture is a reference picture and after all slices of the current picture have been decoded, the decoded reference picture marking process in subclause 8.2.5 specifies how the current picture is used in the decoding process of inter prediction in later decoded pictures.
- The processes in subclauses 8.3, 8.4, 8.5, 8.6, and 8.7 specify decoding processes using syntax elements in the macroblock layer and above.
 - The intra prediction process for I and SI macroblocks, except for I_PCM macroblocks as specified in subclause 8.3, has intra prediction samples as its output. For I_PCM macroblocks subclause 8.3 directly specifies a picture construction process. The output are the constructed samples prior to the deblocking filter process.
 - The inter prediction process for P and B macroblocks is specified in subclause 8.4 with inter prediction samples being the output.
 - The transform coefficient decoding process and picture construction process prior to deblocking filter process are specified in subclause 8.5. That process derives samples for I and B macroblocks and for P macroblocks in P slices. The output are constructed samples prior to the deblocking filter process.
 - The decoding process for P macroblocks in SP slices or SI macroblocks is specified in subclause 8.6. That process derives samples for P macroblocks in SP slices and for SI macroblocks. The output are constructed samples prior to the deblocking filter process.
 - The constructed samples prior to the deblocking filter process that are next to the edges of blocks and macroblocks are processed by a deblocking filter as specified in subclause 8.7 with the output being the decoded samples.

8.1 NAL unit decoding process

Inputs to this process are NAL units.

Outputs of this process are the RBSP syntax structures encapsulated within the NAL units.

The decoding process for each NAL unit extracts the RBSP syntax structure from the NAL unit and then operates the decoding processes specified for the RBSP syntax structure in the NAL unit as follows.

Subclause 8.2 describes the decoding process for NAL units with `nal_unit_type` equal to 1 through 5.

Subclauses 8.3 describes the decoding process for a macroblock or part of a macroblock coded in NAL units with `nal_unit_type` equal to 1, 2, and 5.

Subclause 8.4 describes the decoding process for a macroblock or part of a macroblock coded in NAL units with `nal_unit_type` equal to 1 and 2.

Subclause 8.5 describes the decoding process for a macroblock or part of a macroblock coded in NAL units with `nal_unit_type` equal to 1 and 3 to 5.

Subclause 8.6 describes the decoding process for a macroblock or part of a macroblock coded in NAL units with `nal_unit_type` equal to 1 and 3 to 5.

Subclause 8.7 describes the decoding process for a macroblock or part of a macroblock coded in NAL units with `nal_unit_type` equal to 1 to 5.

NAL units with `nal_unit_type` equal to 7 and 8 contain sequence parameter sets and picture parameter sets, respectively. Picture parameter sets are used in the decoding processes of other NAL units as determined by reference to a picture parameter set within the slice headers of each picture. Sequence parameter sets are used in the decoding processes of other NAL units as determined by reference to a sequence parameter set within the picture parameter sets of each sequence.

No normative decoding process is specified for NAL units with `nal_unit_type` equal to 6, 9, 10, 11, and 12.

8.2 Slice decoding process

8.2.1 Decoding process for picture order count

Outputs of this process are `TopFieldOrderCnt` (if applicable) and `BottomFieldOrderCnt` (if applicable).

Picture order counts are used to determine initial picture orderings for reference pictures in the decoding of B slices (see subclauses 8.2.4.2.3 and 8.2.4.2.4), to represent picture order differences between frames or fields for motion vector derivation in temporal direct mode (see subclause 8.4.1.2.3), for implicit mode weighted prediction in B slices (see subclause 8.4.2.3.2), and for decoder conformance checking (see subclause C.4).

Picture order count information is derived for every frame, field (whether decoded from a coded field or as a part of a decoded frame), or complementary field pair as follows:

- Each coded frame is associated with two picture order counts, called `TopFieldOrderCnt` and `BottomFieldOrderCnt` for its top field and bottom field, respectively.
- Each coded field is associated with a picture order count, called `TopFieldOrderCnt` for a coded top field and `BottomFieldOrderCnt` for a bottom field.
- Each complementary field pair is associated with two picture order counts, which are the `TopFieldOrderCnt` for its coded top field and the `BottomFieldOrderCnt` for its coded bottom field, respectively.

`TopFieldOrderCnt` and `BottomFieldOrderCnt` indicate the picture order of the corresponding top field or bottom field relative to the first output field of the previous IDR picture or the previous reference picture including a `memory_management_control_operation` equal to 5 in decoding order.

`TopFieldOrderCnt` and `BottomFieldOrderCnt` are derived by invoking one of the decoding processes for picture order count type 0, 1, and 2 in subclauses 8.2.1.1, 8.2.1.2, and 8.2.1.3, respectively. When the current picture includes a memory management control operation equal to 5, after the decoding of the current picture, `tempPicOrderCnt` is set equal to `PicOrderCnt(CurrPic)`, `TopFieldOrderCnt` of the current picture (if any) is set equal to `TopFieldOrderCnt - tempPicOrderCnt`, and `BottomFieldOrderCnt` of the current picture (if any) is set equal to `BottomFieldOrderCnt - tempPicOrderCnt`.

The bitstream shall not contain data that results in $\text{Min}(\text{TopFieldOrderCnt}, \text{BottomFieldOrderCnt})$ not equal to 0 for a coded IDR frame, `TopFieldOrderCnt` not equal to 0 for a coded IDR top field, or `BottomFieldOrderCnt` not equal to 0 for a coded IDR bottom field. Thus, at least one of `TopFieldOrderCnt` and `BottomFieldOrderCnt` shall be equal to 0 for the fields of a coded IDR frame.

When the current picture is not an IDR picture, the following applies.

- Consider the list variable `listD` containing as elements the `TopFieldOrderCnt` and `BottomFieldOrderCnt` values associated with the list of pictures including all of the following
 - the first picture in the list is the previous picture of any of the following types
 - an IDR picture
 - a picture containing a `memory_management_control_operation` equal to 5
 - the following additional pictures.

- If `pic_order_cnt_type` is equal to 0, all other pictures that follow in decoding order after the first picture in the list and are not "non-existing" frames inferred by the decoding process for gaps in `frame_num` specified in subclause 8.2.5.2 and either precede the current picture in decoding order or are the current picture. When `pic_order_cnt_type` is equal to 0 and the current picture is not a "non-existing" frame inferred by the decoding process for gaps in `frame_num` specified in subclause 8.2.5.2, the current picture is included in `listD` prior to the invoking of the decoded reference picture marking process.

Otherwise (`pic_order_cnt_type` is not equal to 0), all other pictures that follow in decoding order after the first picture in the list and either precede the current picture in decoding order or are the current picture. When `pic_order_cnt_type` is not equal to 0, the current picture is included in `listD` prior to the invoking of the decoded reference picture marking process.

- Consider the list variable `listO` which contains the elements of `listD` sorted in ascending order. `listO` shall not contain any of the following.
 - a pair of `TopFieldOrderCnt` and `BottomFieldOrderCnt` for a frame or complementary field pair that are not at consecutive positions in `listO`.
 - a `TopFieldOrderCnt` that has a value equal to another `TopFieldOrderCnt`.
 - a `BottomFieldOrderCnt` that has a value equal to another `BottomFieldOrderCnt`.
 - a `BottomFieldOrderCnt` that has a value equal to a `TopFieldOrderCnt` unless the `BottomFieldOrderCnt` and `TopFieldOrderCnt` belong to the same coded frame or complementary field pair.

The bitstream shall not contain data that results in values of `TopFieldOrderCnt`, `BottomFieldOrderCnt`, `PicOrderCntMsb`, or `FrameNumOffset` used in the decoding process as specified in subclauses 8.2.1.1 to 8.2.1.3 that exceed the range of values from -2^{31} to $2^{31}-1$, inclusive.

The function `PicOrderCnt(picX)` is specified as follows:

```

if( picX is a frame or a complementary field pair )
    PicOrderCnt( picX ) = Min( TopFieldOrderCnt, BottomFieldOrderCnt ) of the frame or complementary field
    pair picX
else if( picX is a top field )
    PicOrderCnt( picX ) = TopFieldOrderCnt of field picX
else if( picX is a bottom field )
    PicOrderCnt( picX ) = BottomFieldOrderCnt of field picX

```

(8-1)

Then `DiffPicOrderCnt(picA, picB)` is specified as follows:

$$\text{DiffPicOrderCnt}(\text{picA}, \text{picB}) = \text{PicOrderCnt}(\text{picA}) - \text{PicOrderCnt}(\text{picB}) \quad (8-2)$$

The bitstream shall not contain data that results in values of `DiffPicOrderCnt(picA, picB)` used in the decoding process that exceed the range of -2^{15} to $2^{15} - 1$, inclusive.

NOTE 1 – 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.

NOTE 2 – Many applications assign `PicOrderCnt(X)` proportional to the sampling time of the picture X relative to the sampling time of an IDR picture.

When the current picture includes a `memory_management_control_operation` equal to 5, `PicOrderCnt(CurrPic)` shall be greater than `PicOrderCnt(any other picture in listD)`.

8.2.1.1 Decoding process for picture order count type 0

This process is invoked when `pic_order_cnt_type` is equal to 0.

Input to this process is `PicOrderCntMsb` of the previous reference picture in decoding order as specified in this subclause.

Outputs of this process are either or both `TopFieldOrderCnt` or `BottomFieldOrderCnt`.

The variables `prevPicOrderCntMsb` and `prevPicOrderCntLsb` are derived as follows.

- If the current picture is an IDR picture, `prevPicOrderCntMsb` is set equal to 0 and `prevPicOrderCntLsb` is set equal to 0.
- Otherwise (the current picture is not an IDR picture), the following applies.

- If the previous reference picture in decoding order included a memory_management_control_operation equal to 5, the following applies.
 - If the previous reference picture in decoding order is not a bottom field, prevPicOrderCntMsb is set equal to 0 and prevPicOrderCntLsb is set equal to the value of TopFieldOrderCnt for the previous reference picture in decoding order.
 - Otherwise (the previous reference picture in decoding order is a bottom field), prevPicOrderCntMsb is set equal to 0 and prevPicOrderCntLsb is set equal to 0.
- Otherwise (the previous reference picture in decoding order did not include a memory_management_control_operation equal to 5), prevPicOrderCntMsb is set equal to PicOrderCntMsb of the previous reference picture in decoding order and prevPicOrderCntLsb is set equal to the value of pic_order_cnt_lsb of the previous reference picture in decoding order.

PicOrderCntMsb of the current picture is derived as follows:

```

if( ( pic_order_cnt_lsb < prevPicOrderCntLsb ) &&
    ( ( prevPicOrderCntLsb - pic_order_cnt_lsb ) >= ( MaxPicOrderCntLsb / 2 ) ) )
    PicOrderCntMsb = prevPicOrderCntMsb + MaxPicOrderCntLsb
else if( ( pic_order_cnt_lsb > prevPicOrderCntLsb ) &&
        ( ( pic_order_cnt_lsb - prevPicOrderCntLsb ) > ( MaxPicOrderCntLsb / 2 ) ) )
    PicOrderCntMsb = prevPicOrderCntMsb - MaxPicOrderCntLsb
else
    PicOrderCntMsb = prevPicOrderCntMsb

```

(8-3)

When the current picture is not a bottom field, TopFieldOrderCnt is derived as follows:

```

if( !field_pic_flag || !bottom_field_flag )
    TopFieldOrderCnt = PicOrderCntMsb + pic_order_cnt_lsb

```

(8-4)

When the current picture is not a top field, BottomFieldOrderCnt is derived as follows:

```

if( !field_pic_flag )
    BottomFieldOrderCnt = TopFieldOrderCnt + delta_pic_order_cnt_bottom
else if( bottom_field_flag )
    BottomFieldOrderCnt = PicOrderCntMsb + pic_order_cnt_lsb

```

(8-5)

8.2.1.2 Decoding process for picture order count type 1

This process is invoked when pic_order_cnt_type is equal to 1.

Input to this process is FrameNumOffset of the previous picture in decoding order as specified in this subclause.

Outputs of this process are either or both TopFieldOrderCnt or BottomFieldOrderCnt.

The values of TopFieldOrderCnt and BottomFieldOrderCnt are derived as specified in this subclause. Let prevFrameNum be equal to the frame_num of the previous picture in decoding order.

When the current picture is not an IDR picture, the variable prevFrameNumOffset is derived as follows.

- If the previous picture in decoding order included a memory_management_control_operation equal to 5, prevFrameNumOffset is set equal to 0.
 - Otherwise (the previous picture in decoding order did not include a memory_management_control_operation equal to 5), prevFrameNumOffset is set equal to the value of FrameNumOffset of the previous picture in decoding order.
- NOTE – When gaps_in_frame_num_value_allowed_flag is equal to 1, the previous picture in decoding order may be a "non-existing" frame inferred by the decoding process for gaps in frame_num specified in subclause 8.2.5.2.

The derivation proceeds in the following ordered steps.

1. The variable FrameNumOffset is derived as follows:

```

if( nal_unit_type == 5 )
    FrameNumOffset = 0
else if( prevFrameNum > frame_num )
    FrameNumOffset = prevFrameNumOffset + MaxFrameNum

```

(8-6)

```

else
    FrameNumOffset = prevFrameNumOffset

```

2. The variable `absFrameNum` is derived as follows:

```

if( num_ref_frames_in_pic_order_cnt_cycle != 0 )
    absFrameNum = FrameNumOffset + frame_num
else
    absFrameNum = 0
if( nal_ref_idc == 0 && absFrameNum > 0 )
    absFrameNum = absFrameNum - 1

```

(8-7)

3. When `absFrameNum > 0`, `picOrderCntCycleCnt` and `frameNumInPicOrderCntCycle` are derived as follows:

```

if( absFrameNum > 0 ) {
    picOrderCntCycleCnt = ( absFrameNum - 1 ) / num_ref_frames_in_pic_order_cnt_cycle
    frameNumInPicOrderCntCycle = ( absFrameNum - 1 ) % num_ref_frames_in_pic_order_cnt_cycle
}

```

(8-8)

4. The variable `expectedDeltaPerPicOrderCntCycle` is derived as follows:

```

expectedDeltaPerPicOrderCntCycle = 0
for( i = 0; i < num_ref_frames_in_pic_order_cnt_cycle; i++ )
    expectedDeltaPerPicOrderCntCycle += offset_for_ref_frame[ i ]

```

(8-9)

5. The variable `expectedPicOrderCnt` is derived as follows:

```

if( absFrameNum > 0 ){
    expectedPicOrderCnt = picOrderCntCycleCnt * expectedDeltaPerPicOrderCntCycle
    for( i = 0; i <= frameNumInPicOrderCntCycle; i++ )
        expectedPicOrderCnt = expectedPicOrderCnt + offset_for_ref_frame[ i ]
} else
    expectedPicOrderCnt = 0
if( nal_ref_idc == 0 )
    expectedPicOrderCnt = expectedPicOrderCnt + offset_for_non_ref_pic

```

(8-10)

6. The variables `TopFieldOrderCnt` or `BottomFieldOrderCnt` are derived as follows:

```

if( !field_pic_flag ) {
    TopFieldOrderCnt = expectedPicOrderCnt + delta_pic_order_cnt[ 0 ]
    BottomFieldOrderCnt = TopFieldOrderCnt +
        offset_for_top_to_bottom_field + delta_pic_order_cnt[ 1 ]
} else if( !bottom_field_flag )
    TopFieldOrderCnt = expectedPicOrderCnt + delta_pic_order_cnt[ 0 ]
else
    BottomFieldOrderCnt = expectedPicOrderCnt + offset_for_top_to_bottom_field + delta_pic_order_cnt[ 0 ]

```

(8-11)

8.2.1.3 Decoding process for picture order count type 2

This process is invoked when `pic_order_cnt_type` is equal to 2.

Outputs of this process are either or both `TopFieldOrderCnt` or `BottomFieldOrderCnt`.

Let `prevFrameNum` be equal to the `frame_num` of the previous picture in decoding order.

When the current picture is not an IDR picture, the variable `prevFrameNumOffset` is derived as follows.

- If the previous picture in decoding order included a `memory_management_control_operation` equal to 5, `prevFrameNumOffset` is set equal to 0.
- Otherwise (the previous picture in decoding order did not include a `memory_management_control_operation` equal to 5), `prevFrameNumOffset` is set equal to the value of `FrameNumOffset` of the previous picture in decoding order.

NOTE 1 – When `gaps_in_frame_num_value_allowed_flag` is equal to 1, the previous picture in decoding order may be a "non-existing" frame inferred by the decoding process for gaps in `frame_num` specified in subclause 8.2.5.2.

The variable `FrameNumOffset` is derived as follows.

```

if( nal_unit_type == 5 )
    FrameNumOffset = 0
else if( prevFrameNum > frame_num )
    FrameNumOffset = prevFrameNumOffset + MaxFrameNum
else
    FrameNumOffset = prevFrameNumOffset
    
```

(8-12)

The variable `tempPicOrderCnt` is derived as follows:

```

if( nal_unit_type == 5 )
    tempPicOrderCnt = 0
else if( nal_ref_idc == 0 )
    tempPicOrderCnt = 2 * ( FrameNumOffset + frame_num ) - 1
else
    tempPicOrderCnt = 2 * ( FrameNumOffset + frame_num )
    
```

(8-13)

The variables `TopFieldOrderCnt` or `BottomFieldOrderCnt` are derived as follows:

```

if( !field_pic_flag ) {
    TopFieldOrderCnt = tempPicOrderCnt
    BottomFieldOrderCnt = tempPicOrderCnt
} else if( bottom_field_flag )
    BottomFieldOrderCnt = tempPicOrderCnt
else
    TopFieldOrderCnt = tempPicOrderCnt
    
```

(8-14)

NOTE 2 – Picture order count type 2 cannot be used in a coded video sequence that contains consecutive non-reference pictures that would result in more than one of these pictures having the same value of `TopFieldOrderCnt` or more than one of these pictures having the same value of `BottomFieldOrderCnt`.

NOTE 3 – Picture order count type 2 results in an output order that is the same as the decoding order.

8.2.2 Decoding process for macroblock to slice group map

Inputs to this process are the active picture parameter set and the slice header of the slice to be decoded.

Output of this process is a macroblock to slice group map `MbToSliceGroupMap`.

This process is invoked at the start of every slice.

NOTE – The output of this process is equal for all slices of a picture.

When `num_slice_groups_minus1` is equal to 1 and `slice_group_map_type` is equal to 3, 4, or 5, slice groups 0 and 1 have a size and shape determined by `slice_group_change_direction_flag` as shown in Table 8-1 and specified in subclauses 8.2.2.4 to 8.2.2.6.

Table 8-1 – Refined slice group map type

<code>slice_group_map_type</code>	<code>slice_group_change_direction_flag</code>	refined slice group map type
3	0	Box-out clockwise
3	1	Box-out counter-clockwise
4	0	Raster scan
4	1	Reverse raster scan
5	0	Wipe right
5	1	Wipe left

In such a case, MapUnitsInSliceGroup0 slice group map units in the specified growth order are allocated for slice group 0 and the remaining PicSizeInMapUnits – MapUnitsInSliceGroup0 slice group map units of the picture are allocated for slice group 1.

When num_slice_groups_minus1 is equal to 1 and slice_group_map_type is equal to 4 or 5, the variable sizeOfUpperLeftGroup is defined as follows:

$$\text{sizeOfUpperLeftGroup} = (\text{slice_group_change_direction_flag} ? (\text{PicSizeInMapUnits} - \text{MapUnitsInSliceGroup0}) : \text{MapUnitsInSliceGroup0}) \quad (8-15)$$

The variable mapUnitToSliceGroupMap is derived as follows.

- If num_slice_groups_minus1 is equal to 0, the map unit to slice group map is generated for all i ranging from 0 to PicSizeInMapUnits – 1, inclusive, as specified by:

$$\text{mapUnitToSliceGroupMap}[i] = 0 \quad (8-16)$$

- Otherwise (num_slice_groups_minus1 is not equal to 0), mapUnitToSliceGroupMap is derived as follows.
 - If slice_group_map_type is equal to 0, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.1 applies.
 - Otherwise, if slice_group_map_type is equal to 1, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.2 applies.
 - Otherwise, if slice_group_map_type is equal to 2, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.3 applies.
 - Otherwise, if slice_group_map_type is equal to 3, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.4 applies.
 - Otherwise, if slice_group_map_type is equal to 4, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.5 applies.
 - Otherwise, if slice_group_map_type is equal to 5, the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.6 applies.
 - Otherwise (slice_group_map_type is equal to 6), the derivation of mapUnitToSliceGroupMap as specified in subclause 8.2.2.7 applies.

After derivation of the mapUnitToSliceGroupMap, the process specified in subclause 8.2.2.8 is invoked to convert the map unit to slice group map mapUnitToSliceGroupMap to the macroblock to slice group map MbToSliceGroupMap. After derivation of the macroblock to slice group map as specified in subclause 8.2.2.8, the function NextMbAddress(n) is defined as the value of the variable nextMbAddress derived as specified by:

$$\begin{aligned} & i = n + 1 \\ & \text{while}(i < \text{PicSizeInMbs} \ \&\& \ \text{MbToSliceGroupMap}[i] \neq \text{MbToSliceGroupMap}[n]) \\ & \quad i++; \\ & \text{nextMbAddress} = i \end{aligned} \quad (8-17)$$

8.2.2.1 Specification for interleaved slice group map type

The specifications in this subclause apply when slice_group_map_type is equal to 0.

The map unit to slice group map is generated as specified by:

$$\begin{aligned} & i = 0 \\ & \text{do} \\ & \quad \text{for}(iGroup = 0; iGroup \leq \text{num_slice_groups_minus1} \ \&\& \ i < \text{PicSizeInMapUnits}; \\ & \quad \quad i += \text{run_length_minus1}[iGroup++] + 1) \\ & \quad \quad \text{for}(j = 0; j \leq \text{run_length_minus1}[iGroup] \ \&\& \ i + j < \text{PicSizeInMapUnits}; j++) \\ & \quad \quad \quad \text{mapUnitToSliceGroupMap}[i + j] = iGroup \\ & \text{while}(i < \text{PicSizeInMapUnits}) \end{aligned} \quad (8-18)$$

8.2.2.2 Specification for dispersed slice group map type

The specifications in this subclause apply when slice_group_map_type is equal to 1.

The map unit to slice group map is generated as specified by:

```

for( i = 0; i < PicSizeInMapUnits; i++ )
    mapUnitToSliceGroupMap[ i ] = ( ( i % PicWidthInMbs ) +
        ( ( ( i / PicWidthInMbs ) * ( num_slice_groups_minus1 + 1 ) ) / 2 ) )
        % ( num_slice_groups_minus1 + 1 )

```

(8-19)

8.2.2.3 Specification for foreground with left-over slice group map type

The specifications in this subclause apply when slice_group_map_type is equal to 2.

The map unit to slice group map is generated as specified by:

```

for( i = 0; i < PicSizeInMapUnits; i++ )
    mapUnitToSliceGroupMap[ i ] = num_slice_groups_minus1
for( iGroup = num_slice_groups_minus1 - 1; iGroup >= 0; iGroup-- ) {
    yTopLeft = top_left[ iGroup ] / PicWidthInMbs
    xTopLeft = top_left[ iGroup ] % PicWidthInMbs
    yBottomRight = bottom_right[ iGroup ] / PicWidthInMbs
    xBottomRight = bottom_right[ iGroup ] % PicWidthInMbs
    for( y = yTopLeft; y <= yBottomRight; y++ )
        for( x = xTopLeft; x <= xBottomRight; x++ )
            mapUnitToSliceGroupMap[ y * PicWidthInMbs + x ] = iGroup
}

```

(8-20)

NOTE – The rectangles may overlap. Slice group 0 contains the macroblocks that are within the rectangle specified by top_left[0] and bottom_right[0]. A slice group having slice group ID greater than 0 and less than num_slice_groups_minus1 contains the macroblocks that are within the specified rectangle for that slice group that are not within the rectangle specified for any slice group having a smaller slice group ID. The slice group with slice group ID equal to num_slice_groups_minus1 contains the macroblocks that are not in the other slice groups.

8.2.2.4 Specification for box-out slice group map types

The specifications in this subclause apply when slice_group_map_type is equal to 3.

The map unit to slice group map is generated as specified by:

```

for( i = 0; i < PicSizeInMapUnits; i++ )
    mapUnitToSliceGroupMap[ i ] = 1
x = ( PicWidthInMbs - slice_group_change_direction_flag ) / 2
y = ( PicHeightInMapUnits - slice_group_change_direction_flag ) / 2
( leftBound, topBound ) = ( x, y )
( rightBound, bottomBound ) = ( x, y )
( xDir, yDir ) = ( slice_group_change_direction_flag - 1, slice_group_change_direction_flag )
for( k = 0; k < MapUnitsInSliceGroup0; k += mapUnitVacant ) {
    mapUnitVacant = ( mapUnitToSliceGroupMap[ y * PicWidthInMbs + x ] == 1 )
    if( mapUnitVacant )
        mapUnitToSliceGroupMap[ y * PicWidthInMbs + x ] = 0
    if( xDir == -1 && x == leftBound ) {
        leftBound = Max( leftBound - 1, 0 )
        x = leftBound
        ( xDir, yDir ) = ( 0, 2 * slice_group_change_direction_flag - 1 )
    } else if( xDir == 1 && x == rightBound ) {
        rightBound = Min( rightBound + 1, PicWidthInMbs - 1 )
        x = rightBound
        ( xDir, yDir ) = ( 0, 1 - 2 * slice_group_change_direction_flag )
    } else if( yDir == -1 && y == topBound ) {
        topBound = Max( topBound - 1, 0 )
        y = topBound
        ( xDir, yDir ) = ( 1 - 2 * slice_group_change_direction_flag, 0 )
    } else if( yDir == 1 && y == bottomBound ) {
        bottomBound = Min( bottomBound + 1, PicHeightInMapUnits - 1 )
        y = bottomBound
        ( xDir, yDir ) = ( 2 * slice_group_change_direction_flag - 1, 0 )
    } else
}

```

(8-21)

```

    ( x, y ) = ( x + xDir, y + yDir )
}

```

8.2.2.5 Specification for raster scan slice group map types

The specifications in this subclause apply when slice_group_map_type is equal to 4.

The map unit to slice group map is generated as specified by:

```

for( i = 0; i < PicSizeInMapUnits; i++ )
  if( i < sizeOfUpperLeftGroup )
    mapUnitToSliceGroupMap[ i ] = slice_group_change_direction_flag
  else
    mapUnitToSliceGroupMap[ i ] = 1 - slice_group_change_direction_flag

```

(8-22)

8.2.2.6 Specification for wipe slice group map types

The specifications in this subclause apply when slice_group_map_type is equal to 5.

The map unit to slice group map is generated as specified by:

```

k = 0;
for( j = 0; j < PicWidthInMbs; j++ )
  for( i = 0; i < PicHeightInMapUnits; i++ )
    if( k++ < sizeOfUpperLeftGroup )
      mapUnitToSliceGroupMap[ i * PicWidthInMbs + j ] = slice_group_change_direction_flag
    else
      mapUnitToSliceGroupMap[ i * PicWidthInMbs + j ] = 1 - slice_group_change_direction_flag

```

(8-23)

8.2.2.7 Specification for explicit slice group map type

The specifications in this subclause apply when slice_group_map_type is equal to 6.

The map unit to slice group map is generated as specified by:

$$\text{mapUnitToSliceGroupMap}[i] = \text{slice_group_id}[i] \quad (8-24)$$

for all i ranging from 0 to PicSizeInMapUnits – 1, inclusive.

8.2.2.8 Specification for conversion of map unit to slice group map to macroblock to slice group map

For each value of i ranging from 0 to PicSizeInMbs – 1, inclusive, the macroblock to slice group map is specified as follows.

— If frame_mbs_only_flag is equal to 1 or field_pic_flag is equal to 1, the macroblock to slice group map is specified by:

$$\text{MbToSliceGroupMap}[i] = \text{mapUnitToSliceGroupMap}[i] \quad (8-25)$$

– Otherwise, if MbaffFrameFlag is equal to 1, the macroblock to slice group map is specified by:

$$\text{MbToSliceGroupMap}[i] = \text{mapUnitToSliceGroupMap}[i / 2] \quad (8-26)$$

– Otherwise (frame_mbs_only_flag is equal to 0 and mb_adaptive_frame_field_flag is equal to 0 and field_pic_flag is equal to 0), the macroblock to slice group map is specified by:

$$\text{MbToSliceGroupMap}[i] = \text{mapUnitToSliceGroupMap}[(i / (2 * \text{PicWidthInMbs})) * \text{PicWidthInMbs} + (i \% \text{PicWidthInMbs})] \quad (8-27)$$

8.2.3 Decoding process for slice data partitioning

Inputs to this process are

– a slice data partition A layer RBSP,

- when syntax elements of category 3 are present in the slice data, a slice data partition B layer RBSP having the same slice_id as in the slice data partition A layer RBSP, and
- when syntax elements of category 4 are present in the slice data, a slice data partition C layer RBSP having the same slice_id as in the slice data partition A layer RBSP.

NOTE 1 – The slice data partition B layer RBSP and slice data partition C layer RBSP need not be present.

Output of this process is a coded slice.

When slice data partitioning is not used, coded slices are represented by a slice layer without partitioning RBSP that contains a slice header followed by a slice data syntax structure that contains all the syntax elements of categories 2, 3, and 4 (see category column in subclause 7.3) of the macroblock data for the macroblocks of the slice.

When slice data partitioning is used, the macroblock data of a slice is partitioned into one to three partitions contained in separate NAL units. Partition A contains a slice data partition A header, and all syntax elements of category 2. Partition B, when present, contains a slice data partition B header and all syntax elements of category 3. Partition C, when present, contains a slice data partition C header and all syntax elements of category 4.

When slice data partitioning is used, the syntax elements of each category are parsed from a separate NAL unit, which need not be present when no symbols of the respective category exist. The decoding process shall process the slice data partitions of a coded slice in a manner equivalent to processing a corresponding slice layer without partitioning RBSP by extracting each syntax element from the slice data partition in which the syntax element appears depending on the slice data partition assignment in the syntax tables in subclause 7.3.

NOTE 2 – Syntax elements of category 3 are relevant to the decoding of residual data of I and SI macroblock types. Syntax elements of category 4 are relevant to the decoding of residual data of P and B macroblock types. Category 2 encompasses all other syntax elements related to the decoding of macroblocks, and their information is often denoted as header information. The slice data partition A header contains all the syntax elements of the slice header, and additionally a slice_id that are used to associate the slice data partitions B and C with the slice data partition A. The slice data partition B and C headers contain the slice_id syntax element that establishes their association with the slice data partition A of the slice.

8.2.4 Decoding process for reference picture lists construction

This process is invoked at the beginning of decoding of each P, SP, or B slice.

Decoded reference pictures are marked as "used for short-term reference" or "used for long-term reference" as specified by the bitstream and specified in subclause 8.2.5. Short-term reference pictures are identified by the value of frame_num. Long-term reference pictures are assigned a long-term frame index as specified by the bitstream and specified in subclause 8.2.5.

Subclause 8.2.4.1 is invoked to specify

- the assignment of variables FrameNum, FrameNumWrap, and PicNum to each of the short-term reference pictures, and
- the assignment of variable LongTermPicNum to each of the long-term reference pictures.

Reference pictures are addressed through reference indices as specified in subclause 8.4.2.1. A reference index is an index into a reference picture list. When decoding a P or SP 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 decoding of each slice, reference picture list RefPicList0, and for B slices RefPicList1, are derived as follows.

- An initial reference picture list RefPicList0 and for B slices RefPicList1 are derived as specified in subclause 8.2.4.2.
- The initial reference picture list RefPicList0 and for B slices RefPicList1 are modified as specified in subclause 8.2.4.3.

NOTE – The reordering process for reference picture lists specified in subclause 8.2.4.3 allows the contents of RefPicList0 and for B slices RefPicList1 to be modified in a flexible fashion. In particular, it is possible for a picture that is currently marked "used for reference" to be inserted into RefPicList0 and for B slices RefPicList1 even when the picture is not in the initial reference picture list derived as specified in subclause 8.2.4.2.

The number of entries in the modified reference picture list RefPicList0 is num_ref_idx_l0_active_minus1 + 1, and for B slices the number of entries in the modified reference picture list RefPicList1 is num_ref_idx_l1_active_minus1 + 1. A reference picture may appear at more than one index in the modified reference picture lists RefPicList0 or RefPicList1.

8.2.4.1 Decoding process for picture numbers

This process is invoked when the decoding process for reference picture lists construction specified in subclause 8.2.4 or the decoded reference picture marking process specified in subclause 8.2.5 is invoked.

The variables `FrameNum`, `FrameNumWrap`, `PicNum`, `LongTermFrameIdx`, and `LongTermPicNum` are used for the initialisation process for reference picture lists in subclause 8.2.4.2, the modification process for reference picture lists in subclause 8.2.4.3, and for the decoded reference picture marking process in subclause 8.2.5.

To each short-term reference picture the variables `FrameNum` and `FrameNumWrap` are assigned as follows. First, `FrameNum` is set equal to the syntax element `frame_num` that has been decoded in the slice header(s) of the corresponding short-term reference picture. Then the variable `FrameNumWrap` is derived as

$$\begin{aligned} & \text{if(FrameNum > frame_num)} \\ & \quad \text{FrameNumWrap} = \text{FrameNum} - \text{MaxFrameNum} \\ & \text{else} \\ & \quad \text{FrameNumWrap} = \text{FrameNum} \end{aligned} \tag{8-28}$$

where the value of `frame_num` used in Equation 8-28 is the `frame_num` in the slice header(s) for the current picture.

Each long-term reference picture has an associated value of `LongTermFrameIdx` (that was assigned to it as specified in subclause 8.2.5).

To each short-term reference picture a variable `PicNum` is assigned, and to each long-term reference picture a variable `LongTermPicNum` is assigned. The values of these variables depend on the value of `field_pic_flag` and `bottom_field_flag` for the current picture and they are set as follows.

– If `field_pic_flag` is equal to 0, the following applies.

– For each short-term reference frame or complementary reference field pair:

$$\text{PicNum} = \text{FrameNumWrap} \tag{8-29}$$

– For each long-term reference frame or long-term complementary reference field pair:

$$\text{LongTermPicNum} = \text{LongTermFrameIdx} \tag{8-30}$$

NOTE – When decoding a frame the value of `MbaffFrameFlag` has no influence on the derivations in subclauses 8.2.4.2, 8.2.4.3, and 8.2.5.

– Otherwise (`field_pic_flag` is equal to 1), the following applies.

– For each short-term reference field the following applies.

– If the reference field has the same parity as the current field

$$\text{PicNum} = 2 * \text{FrameNumWrap} + 1 \tag{8-31}$$

– Otherwise (the reference field has the opposite parity of the current field),

$$\text{PicNum} = 2 * \text{FrameNumWrap} \tag{8-32}$$

– For each long-term reference field the following applies.

– If the reference field has the same parity as the current field

$$\text{LongTermPicNum} = 2 * \text{LongTermFrameIdx} + 1 \tag{8-33}$$

– Otherwise (the reference field has the opposite parity of the current field),

$$\text{LongTermPicNum} = 2 * \text{LongTermFrameIdx} \tag{8-34}$$

8.2.4.2 Initialisation process for reference picture lists

This initialisation process is invoked when decoding a P, SP, or B slice header.

RefPicList0 and RefPicList1 have initial entries as specified in subclauses 8.2.4.2.1 through 8.2.4.2.5.

When the number of entries in the initial RefPicList0 or RefPicList1 produced as specified in subclauses 8.2.4.2.1 through 8.2.4.2.5 is greater than $\text{num_ref_idx_l0_active_minus1} + 1$ or $\text{num_ref_idx_l1_active_minus1} + 1$, respectively, the extra entries past position $\text{num_ref_idx_l0_active_minus1}$ or $\text{num_ref_idx_l1_active_minus1}$ are discarded from the initial reference picture list.

When the number of entries in the initial RefPicList0 or RefPicList1 produced as specified in subclauses 8.2.4.2.1 through 8.2.4.2.5 is less than $\text{num_ref_idx_l0_active_minus1} + 1$ or $\text{num_ref_idx_l1_active_minus1} + 1$, respectively, the remaining entries in the initial reference picture list are set equal to "no reference picture".

8.2.4.2.1 Initialisation process for the reference picture list for P and SP slices in frames

This initialisation process is invoked when decoding a P or SP slice in a coded frame.

When this process is invoked, there shall be at least one reference frame or complementary reference field pair that is currently marked as "used for short-term reference" or "used for long-term reference".

The reference picture list RefPicList0 is ordered so that short-term reference frames and short-term complementary reference field pairs have lower indices than long-term reference frames and long-term complementary reference field pairs.

The short-term reference frames and complementary reference field pairs are ordered starting with the frame or complementary field pair with the highest PicNum value and proceeding through in descending order to the frame or complementary field pair with the lowest PicNum value.

The long-term reference frames and complementary reference field pairs are ordered starting with the frame or complementary field pair with the lowest LongTermPicNum value and proceeding through in ascending order to the frame or complementary field pair with the highest LongTermPicNum value.

NOTE – A non-paired reference field is not used for inter prediction for decoding a frame, regardless of the value of MbaffFrameFlag.

For example, when three reference frames are marked as "used for short-term reference" with PicNum equal to 300, 302, and 303 and two reference frames are marked as "used for long-term reference" with LongTermPicNum equal to 0 and 3, the initial index order is:

- RefPicList0[0] is set equal to the short-term reference picture with PicNum = 303,
- RefPicList0[1] is set equal to the short-term reference picture with PicNum = 302,
- RefPicList0[2] is set equal to the short-term reference picture with PicNum = 300,
- RefPicList0[3] is set equal to the long-term reference picture with LongTermPicNum = 0, and
- RefPicList0[4] is set equal to the long-term reference picture with LongTermPicNum = 3.

8.2.4.2.2 Initialisation process for the reference picture list for P and SP slices in fields

This initialisation process is invoked when decoding a P or SP slice in a coded field.

Each field included in the reference picture list RefPicList0 has a separate index in the reference picture list RefPicList0.

NOTE – When decoding a field, there are effectively at least twice as many pictures available for referencing as there would be when decoding a frame at the same position in decoding order.

Two ordered lists of reference frames, refFrameList0ShortTerm and refFrameList0LongTerm, are derived as follows. For purposes of the formation of this list of frames, decoded reference frames, complementary reference field pairs, non-paired reference fields and reference frames in which a single field is marked "used for short-term reference" or "used for long-term reference" are all considered reference frames.

- All frames having one or more fields marked "used for short-term reference" are included in the list of short-term reference frames refFrameList0ShortTerm. When the current field is the second field (in decoding order) of a complementary reference field pair and the first field is marked as "used for short-term reference", the first field is included in the list of short-term reference frames refFrameList0ShortTerm. refFrameList0ShortTerm is ordered starting with the reference frame with the highest FrameNumWrap value and proceeding through in descending order to the reference frame with the lowest FrameNumWrap value.
- All frames having one or more fields marked "used for long-term reference" are included in the list of long-term reference frames refFrameList0LongTerm. When the current field is the second field (in decoding order) of a complementary reference field pair and the first field is marked as "used for long-term reference", the first field is included in the list of long-term reference frames refFrameList0LongTerm. refFrameList0LongTerm is ordered

starting with the reference frame with the lowest LongTermFrameIdx value and proceeding through in ascending order to the reference frame with the highest LongTermFrameIdx value.

The process specified in subclause 8.2.4.2.5 is invoked with refFrameList0ShortTerm and refFrameList0LongTerm given as input and the output is assigned to RefPicList0.

8.2.4.2.3 Initialisation process for reference picture lists for B slices in frames

This initialisation process is invoked when decoding a B slice in a coded frame.

For purposes of the formation of the reference picture lists RefPicList0 and RefPicList1 the term reference entry refers in the following to decoded reference frames or complementary reference field pairs.

When this process is invoked, there shall be at least one reference entry that is currently marked as "used for short-term reference" or "used for long-term reference".

For B slices, the order of short-term reference entries in the reference picture lists RefPicList0 and RefPicList1 depends on output order, as given by PicOrderCnt(). When pic_order_cnt_type is equal to 0, reference pictures that are marked as "non-existing" as specified in subclause 8.2.5.2 are not included in either RefPicList0 or RefPicList1.

NOTE 1 – When gaps_in_frame_num_value_allowed_flag is equal to 1, encoders should use reference picture list reordering to ensure proper operation of the decoding process (particularly when pic_order_cnt_type is equal to 0, in which case PicOrderCnt() is not inferred for "non-existing" frames).

The reference picture list RefPicList0 is ordered such that short-term reference entries have lower indices than long-term reference entries. It is ordered as follows.

- Let entryShortTerm be a variable ranging over all reference entries that are currently marked as "used for short-term reference". When some values of entryShortTerm are present having PicOrderCnt(entryShortTerm) less than PicOrderCnt(CurrPic), these values of entryShortTerm are placed at the beginning of refPicList0 in descending order of PicOrderCnt(entryShortTerm). All of the remaining values of entryShortTerm (when present) are then appended to refPicList0 in ascending order of PicOrderCnt(entryShortTerm).
- The long-term reference entries are ordered starting with the long-term reference entry that has the lowest LongTermPicNum value and proceeding through in ascending order to the long-term reference entry that has the highest LongTermPicNum value.

The reference picture list RefPicList1 is ordered so that short-term reference entries have lower indices than long-term reference entries. It is ordered as follows.

- Let entryShortTerm be a variable ranging over all reference entries that are currently marked as "used for short-term reference". When some values of entryShortTerm are present having PicOrderCnt(entryShortTerm) greater than PicOrderCnt(CurrPic), these values of entryShortTerm are placed at the beginning of refPicList1 in ascending order of PicOrderCnt(entryShortTerm). All of the remaining values of entryShortTerm (when present) are then appended to refPicList1 in descending order of PicOrderCnt(entryShortTerm).
- Long-term reference entries are ordered starting with the long-term reference frame or complementary reference field pair that has the lowest LongTermPicNum value and proceeding through in ascending order to the long-term reference entry that has the highest LongTermPicNum value.
- When the reference picture list RefPicList1 has more than one entry and RefPicList1 is identical to the reference picture list RefPicList0, the first two entries RefPicList1[0] and RefPicList1[1] are switched.

NOTE 2 – A non-paired reference field is not used for inter prediction of frames (independent of the value of MbaffFrameFlag).

8.2.4.2.4 Initialisation process for reference picture lists for B slices in fields

This initialisation process is invoked when decoding a B slice in a coded field.

When decoding a field, each field of a stored reference frame is identified as a separate reference picture with a unique index. The order of short-term reference pictures in the reference picture lists RefPicList0 and RefPicList1 depend on output order, as given by PicOrderCnt(). When pic_order_cnt_type is equal to 0, reference pictures that are marked as "non-existing" as specified in subclause 8.2.5.2 are not included in either RefPicList0 or RefPicList1.

NOTE 1 – When gaps_in_frame_num_value_allowed_flag is equal to 1, encoders should use reference picture list reordering to ensure proper operation of the decoding process (particularly when pic_order_cnt_type is equal to 0, in which case PicOrderCnt() is not inferred for "non-existing" frames).

NOTE 2 – When decoding a field, there are effectively at least twice as many pictures available for referencing as there would be when decoding a frame at the same position in decoding order.

Three ordered lists of reference frames, refFrameList0ShortTerm, refFrameList1ShortTerm and refFrameListLongTerm, are derived as follows. For purposes of the formation of these lists of frames the term reference entry refers in the following to decoded reference frames, complementary reference field pairs, or non-paired reference

fields. When `pic_order_cnt_type` is equal to 0, the term reference entry does not refer to frames that are marked as "non-existing" as specified in subclause 8.2.5.2.

- Let `entryShortTerm` be a variable ranging over all reference entries that are currently marked as "used for short-term reference". When some values of `entryShortTerm` are present having `PicOrderCnt(entryShortTerm)` less than or equal to `PicOrderCnt(CurrPic)`, these values of `entryShortTerm` are placed at the beginning of `refFrameList0ShortTerm` in descending order of `PicOrderCnt(entryShortTerm)`. All of the remaining values of `entryShortTerm` (when present) are then appended to `refFrameList0ShortTerm` in ascending order of `PicOrderCnt(entryShortTerm)`.

NOTE 3 – When the current field follows in decoding order a coded field `fldPrev` with which together it forms a complementary reference field pair, `fldPrev` is included into the list `refFrameList0ShortTerm` using `PicOrderCnt(fldPrev)` and the ordering method described in the previous sentence is applied.

- Let `entryShortTerm` be a variable ranging over all reference entries that are currently marked as "used for short-term reference". When some values of `entryShortTerm` are present having `PicOrderCnt(entryShortTerm)` greater than `PicOrderCnt(CurrPic)`, these values of `entryShortTerm` are placed at the beginning of `refFrameList1ShortTerm` in ascending order of `PicOrderCnt(entryShortTerm)`. All of the remaining values of `entryShortTerm` (when present) are then appended to `refFrameList1ShortTerm` in descending order of `PicOrderCnt(entryShortTerm)`.

NOTE 4 – When the current field follows in decoding order a coded field `fldPrev` with which together it forms a complementary reference field pair, `fldPrev` is included into the list `refFrameList1ShortTerm` using `PicOrderCnt(fldPrev)` and the ordering method described in the previous sentence is applied.

- `refFrameListLongTerm` is ordered starting with the reference entry having the lowest `LongTermFrameIdx` value and proceeding through in ascending order to the reference entry having highest `LongTermFrameIdx` value.

NOTE 5 – When the complementary field of the current picture is marked "used for long-term reference" it is included into the list `refFrameListLongTerm`. A reference entry in which only one field is marked as "used for long-term reference" is included into the list `refFrameListLongTerm`.

The process specified in subclause 8.2.4.2.5 is invoked with `refFrameList0ShortTerm` and `refFrameListLongTerm` given as input and the output is assigned to `RefPicList0`.

The process specified in subclause 8.2.4.2.5 is invoked with `refFrameList1ShortTerm` and `refFrameListLongTerm` given as input and the output is assigned to `RefPicList1`.

When the reference picture list `RefPicList1` has more than one entry and `RefPicList1` is identical to the reference picture list `RefPicList0`, the first two entries `RefPicList1[0]` and `RefPicList1[1]` are switched.

8.2.4.2.5 Initialisation process for reference picture lists in fields

Inputs of this process are the reference frame lists `refFrameListXShortTerm` (with `X` may be 0 or 1) and `refFrameListLongTerm`.

The reference picture list `RefPicListX` is a list ordered such that short-term reference fields have lower indices than long-term reference fields. Given the reference frame lists `refFrameListXShortTerm` and `refFrameListLongTerm`, it is derived as follows.

- Short-term reference fields are ordered by selecting reference fields from the ordered list of frames `refFrameListXShortTerm` by alternating between fields of differing parity, starting with a field that has the same parity as the current field (when present). When one field of a reference frame was not decoded or is not marked as "used for short-term reference", the missing field is ignored and instead the next available stored reference field of the chosen parity from the ordered list of frames `refFrameListXShortTerm` is inserted into `RefPicListX`. When there are no more short-term reference fields of the alternate parity in the ordered list of frames `refFrameListXShortTerm`, the next not yet indexed fields of the available parity are inserted into `RefPicListX` in the order in which they occur in the ordered list of frames `refFrameListXShortTerm`.
- Long-term reference fields are ordered by selecting reference fields from the ordered list of frames `refFrameListLongTerm` by alternating between fields of differing parity, starting with a field that has the same parity as the current field (when present). When one field of a reference frame was not decoded or is not marked as "used for long-term reference", the missing field is ignored and instead the next available stored reference field of the chosen parity from the ordered list of frames `refFrameListLongTerm` is inserted into `RefPicListX`. When there are no more long-term reference fields of the alternate parity in the ordered list of frames `refFrameListLongTerm`, the next not yet indexed fields of the available parity are inserted into `RefPicListX` in the order in which they occur in the ordered list of frames `refFrameListLongTerm`.

8.2.4.3 Reordering process for reference picture lists

When `ref_pic_list_reordering_flag_10` is equal to 1, the following applies.

- Let `refIdxL0` be an index into the reference picture list `RefPicList0`. It is initially set equal to 0.

- The corresponding syntax elements `reordering_of_pic_nums_idc` are processed in the order they occur in the bitstream. For each of these syntax elements, the following applies.
 - If `reordering_of_pic_nums_idc` is equal to 0 or equal to 1, the process specified in subclause 8.2.4.3.1 is invoked with `refIdxL0` as input, and the output is assigned to `refIdxL0`.
 - Otherwise, if `reordering_of_pic_nums_idc` is equal to 2, the process specified in subclause 8.2.4.3.2 is invoked with `refIdxL0` as input, and the output is assigned to `refIdxL0`.
 - Otherwise (`reordering_of_pic_nums_idc` is equal to 3), the reordering process for reference picture list `RefPicList0` is finished.

When `ref_pic_list_reordering_flag_l1` is equal to 1, the following applies.

- Let `refIdxL1` be an index into the reference picture list `RefPicList1`. It is initially set equal to 0.
- The corresponding syntax elements `reordering_of_pic_nums_idc` are processed in the order they occur in the bitstream. For each of these syntax elements, the following applies.
 - If `reordering_of_pic_nums_idc` is equal to 0 or equal to 1, the process specified in subclause 8.2.4.3.1 is invoked with `refIdxL1` as input, and the output is assigned to `refIdxL1`.
 - Otherwise, if `reordering_of_pic_nums_idc` is equal to 2, the process specified in subclause 8.2.4.3.2 is invoked with `refIdxL1` as input, and the output is assigned to `refIdxL1`.
 - Otherwise (`reordering_of_pic_nums_idc` is equal to 3), the reordering process for reference picture list `RefPicList1` is finished.

8.2.4.3.1 Reordering process of reference picture lists for short-term reference pictures

Input to this process is an index `refIdxLX` (with `X` being 0 or 1).

Output of this process is an incremented index `refIdxLX`.

The variable `picNumLXNoWrap` is derived as follows.

- If `reordering_of_pic_nums_idc` is equal to 0

$$\begin{aligned}
 &\text{if}(\text{picNumLXPred} - (\text{abs_diff_pic_num_minus1} + 1) < 0) \\
 &\quad \text{picNumLXNoWrap} = \text{picNumLXPred} - (\text{abs_diff_pic_num_minus1} + 1) + \text{MaxPicNum} \\
 &\text{else} \\
 &\quad \text{picNumLXNoWrap} = \text{picNumLXPred} - (\text{abs_diff_pic_num_minus1} + 1)
 \end{aligned} \tag{8-35}$$

- Otherwise (`reordering_of_pic_nums_idc` is equal to 1),

$$\begin{aligned}
 &\text{if}(\text{picNumLXPred} + (\text{abs_diff_pic_num_minus1} + 1) \geq \text{MaxPicNum}) \\
 &\quad \text{picNumLXNoWrap} = \text{picNumLXPred} + (\text{abs_diff_pic_num_minus1} + 1) - \text{MaxPicNum} \\
 &\text{else} \\
 &\quad \text{picNumLXNoWrap} = \text{picNumLXPred} + (\text{abs_diff_pic_num_minus1} + 1)
 \end{aligned} \tag{8-36}$$

`picNumLXPred` is the prediction value for the variable `picNumLXNoWrap`. When the process specified in this subclause is invoked the first time for a slice (that is, for the first occurrence of `reordering_of_pic_nums_idc` equal to 0 or 1 in the `ref_pic_list_reordering()` syntax), `picNumL0Pred` and `picNumL1Pred` are initially set equal to `CurrPicNum`. After each assignment of `picNumLXNoWrap`, the value of `picNumLXNoWrap` is assigned to `picNumLXPred`.

The variable `picNumLX` is derived as follows

$$\begin{aligned}
 &\text{if}(\text{picNumLXNoWrap} > \text{CurrPicNum}) \\
 &\quad \text{picNumLX} = \text{picNumLXNoWrap} - \text{MaxPicNum} \\
 &\text{else} \\
 &\quad \text{picNumLX} = \text{picNumLXNoWrap}
 \end{aligned} \tag{8-37}$$

`picNumLX` shall be equal to the `PicNum` of a reference picture that is marked as “used for short-term reference” and shall not be equal to the `PicNum` of a short-term reference picture that is marked as “non-existing”.

The following procedure is conducted to place the picture with short-term picture number `picNumLX` into the index position `refIdxLX`, shift the position of any other remaining pictures to later in the list, and increment the value of `refIdxLX`.

```

for( cIdx = num_ref_idx_IX_active_minus1 + 1; cIdx > refIdxLX; cIdx-- )
  RefPicListX[ cIdx ] = RefPicListX[ cIdx - 1 ]
RefPicListX[ refIdxLX++ ] = short-term reference picture with PicNum equal to picNumLX
nIdx = refIdxLX
for( cIdx = refIdxLX; cIdx <= num_ref_idx_IX_active_minus1 + 1; cIdx++ )
  if( PicNumF( RefPicListX[ cIdx ] ) != picNumLX )
    RefPicListX[ nIdx++ ] = RefPicListX[ cIdx ]

```

(8-38)

where the function PicNumF(RefPicListX[cIdx]) is derived as follows:

- If the picture RefPicListX[cIdx] is marked as "used for short-term reference", PicNumF(RefPicListX[cIdx]) is the PicNum of the picture RefPicListX[cIdx].
- Otherwise (the picture RefPicListX[cIdx] is not marked as "used for short-term reference"), PicNumF(RefPicListX[cIdx]) is equal to MaxPicNum.

NOTE 1 – A value of MaxPicNum can never be equal to picNumLX.

NOTE 2 – Within this pseudo-code procedure, the length of the list RefPicListX is temporarily made one element longer than the length needed for the final list. After the execution of this procedure, only elements 0 through num_ref_idx_IX_active_minus1 of the list need to be retained.

8.2.4.3.2 Reordering process of reference picture lists for long-term reference pictures

Input to this process is an index refIdxLX (with X being 0 or 1).

Output of this process is an incremented index refIdxLX.

The following procedure is conducted to place the picture with long-term picture number long_term_pic_num into the index position refIdxLX, shift the position of any other remaining pictures to later in the list, and increment the value of refIdxLX.

```

for( cIdx = num_ref_idx_IX_active_minus1 + 1; cIdx > refIdxLX; cIdx-- )
  RefPicListX[ cIdx ] = RefPicListX[ cIdx - 1 ]
RefPicListX[ refIdxLX++ ] = long-term reference picture with LongTermPicNum equal to long_term_pic_num
nIdx = refIdxLX
for( cIdx = refIdxLX; cIdx <= num_ref_idx_IX_active_minus1 + 1; cIdx++ )
  if( LongTermPicNumF( RefPicListX[ cIdx ] ) != long_term_pic_num )
    RefPicListX[ nIdx++ ] = RefPicListX[ cIdx ]

```

(8-39)

where the function LongTermPicNumF(RefPicListX[cIdx]) is derived as follows:

- If the picture RefPicListX[cIdx] is marked as "used for long-term reference", LongTermPicNumF(RefPicListX[cIdx]) is the LongTermPicNum of the picture RefPicListX[cIdx].
- Otherwise (the picture RefPicListX[cIdx] is not marked as "used for long-term reference"), LongTermPicNumF(RefPicListX[cIdx]) is equal to 2 * (MaxLongTermFrameIdx + 1).

NOTE 1 – A value of 2 * (MaxLongTermFrameIdx + 1) can never be equal to long_term_pic_num.

NOTE 2 – Within this pseudo-code procedure, the length of the list RefPicListX is temporarily made one element longer than the length needed for the final list. After the execution of this procedure, only elements 0 through num_ref_idx_IX_active_minus1 of the list need to be retained.

8.2.5 Decoded reference picture marking process

This process is invoked for decoded pictures when nal_ref_idc is not equal to 0.

NOTE – The decoding process for gaps in frame_num that is specified in subclause 8.2.5.2 may also be invoked when nal_ref_idc is equal to 0, as specified in clause 8.

A decoded picture with nal_ref_idc not equal to 0, referred to as a reference picture, is marked as "used for short-term reference" or "used for long-term reference". For a decoded reference frame, both of its fields are marked the same as the frame. For a complementary reference field pair, the pair is marked the same as both of its fields. A picture that is marked as "used for short-term reference" is identified by its FrameNum and, when it is a field, by its parity. A picture that is marked as "used for long-term reference" is identified by its LongTermFrameIdx and, when it is a field, by its parity.

Frames or complementary field pairs marked as "used for short-term reference" or as "used for long-term reference" can be used as a reference for inter prediction when decoding a frame until the frame, the complementary field pair, or one of its constituent fields is marked as "unused for reference". A field marked as "used for short-term reference" or as

"used for long-term reference" can be used as a reference for inter prediction when decoding a field until marked as "unused for reference".

A picture can be marked as "unused for reference" by the sliding window reference picture marking process, a first-in, first-out mechanism specified in subclause 8.2.5.3 or by the adaptive memory control reference picture marking process, a customised adaptive marking operation specified in subclause 8.2.5.4.

A short-term reference picture is identified for use in the decoding process by its variables `FrameNum` and `FrameNumWrap` and its picture number `PicNum`, and a long-term reference picture is identified for use in the decoding process by its long-term picture number `LongTermPicNum`. When the current picture is not an IDR picture, subclause 8.2.4.1 is invoked to specify the assignment of the variables `FrameNum`, `FrameNumWrap`, `PicNum` and `LongTermPicNum`.

8.2.5.1 Sequence of operations for decoded reference picture marking process

Decoded reference picture marking proceeds in the following ordered steps.

1. All slices of the current picture are decoded.
2. Depending on whether the current picture is an IDR picture, the following applies.
 - If the current picture is an IDR picture, the following applies.
 - All reference pictures are marked as "unused for reference"
 - Depending on `long_term_reference_flag`, the following applies.
 - If `long_term_reference_flag` is equal to 0, the IDR picture is marked as "used for short-term reference" and `MaxLongTermFrameIdx` is set equal to "no long-term frame indices".
 - Otherwise (`long_term_reference_flag` is equal to 1), the IDR picture is marked as "used for long-term reference", the `LongTermFrameIdx` for the IDR picture is set equal to 0, and `MaxLongTermFrameIdx` is set equal to 0.
 - Otherwise (the current picture is not an IDR picture), the following applies.
 - If `adaptive_ref_pic_marking_mode_flag` is equal to 0, the process specified in subclause 8.2.5.3 is invoked.
 - Otherwise (`adaptive_ref_pic_marking_mode_flag` is equal to 1), the process specified in subclause 8.2.5.4 is invoked.
3. When the current picture is not an IDR picture and it was not marked as "used for long-term reference" by `memory_management_control_operation` equal to 6, it is marked as "used for short-term reference".

After marking the current decoded reference picture, the total number of frames with at least one field marked as "used for reference", plus the number of complementary field pairs with at least one field marked as "used for reference", plus the number of non-paired fields marked as "used for reference" shall not be greater than $\text{Max}(\text{num_ref_frames}, 1)$.

8.2.5.2 Decoding process for gaps in `frame_num`

This process is invoked when `frame_num` is not equal to `PrevRefFrameNum` and is not equal to $(\text{PrevRefFrameNum} + 1) \% \text{MaxFrameNum}$.

NOTE 1 – Although this process is specified as a subclause within subclause 8.2.5 (which defines a process that is invoked only when `nal_ref_idc` is not equal to 0), this process may also be invoked when `nal_ref_idc` is equal to 0 (as specified in clause 8). The reasons for the location of this subclause within the structure of this Recommendation | International Standard are historical.

NOTE 2 – This process can only be invoked for a conforming bitstream when `gaps_in_frame_num_value_allowed_flag` is equal to 1. When `gaps_in_frame_num_value_allowed_flag` is equal to 0 and `frame_num` is not equal to `PrevRefFrameNum` and is not equal to $(\text{PrevRefFrameNum} + 1) \% \text{MaxFrameNum}$, the decoding process should infer an unintentional loss of pictures.

When this process is invoked, a set of values of `frame_num` pertaining to "non-existing" pictures is derived as all values taken on by `UnusedShortTermFrameNum` in Equation 7-21 except the value of `frame_num` for the current picture.

The decoding process generates and marks a frame for each of the values of `frame_num` pertaining to "non-existing" pictures, in the order in which the values of `UnusedShortTermFrameNum` are generated by Equation 7-21, using the "sliding window" picture marking process as specified in subclause 8.2.5.3. The generated frames are also marked as "non-existing" and "used for short-term reference". The sample values of the generated frames may be set to any value. The bitstream shall not contain data that results in a reference to these generated frames which are marked as "non-existing" in the inter prediction process, a reference to these frames in the reordering commands for reference picture lists for short-term reference pictures (subclause 8.2.4.3.1), or a reference to these frames in the assignment process of a `LongTermFrameIdx` to a short-term reference picture (subclause 8.2.5.4.3).

When `pic_order_cnt_type` is not equal to 0, `TopFieldOrderCnt` and `BottomFieldOrderCnt` are derived for each of the "non-existing" frames by invoking the decoding process for picture order count in subclause 8.2.1. When invoking the process in subclause 8.2.1 for a particular "non-existing" frame, the current picture is considered to be a picture considered having `frame_num` inferred to be equal to `UnusedShortTermFrameNum`, `nal_ref_idc` inferred to be not equal to 0, `nal_unit_type` inferred to be not equal to 5, `field_pic_flag` inferred to be equal to 0, `adaptive_ref_pic_marking_mode_flag` inferred to be equal to 0, `delta_pic_order_cnt[0]` (if needed) inferred to be equal to 0, and `delta_pic_order_cnt[1]` (if needed) inferred to be equal to 0.

NOTE 3 – The decoding process should infer an unintentional picture loss when any of these values of `frame_num` pertaining to "non-existing" pictures is referred to in the inter prediction process, is referred to in the reordering commands for reference picture lists for short-term reference pictures (subclause 8.2.4.3.1), or is referred to in the assignment process of a `LongTermFrameIdx` to a short-term reference picture (subclause 8.2.5.4.3). The decoding process should not infer an unintentional picture loss when a memory management control operation not equal to 3 is applied to a frame marked as "non-existing".

8.2.5.3 Sliding window decoded reference picture marking process

This process is invoked when `adaptive_ref_pic_marking_mode_flag` is equal to 0.

Depending on the properties of the current picture as specified below, the following applies.

- If the current picture is a coded field that is the second field in decoding order of a complementary reference field pair, and the first field has been marked as "used for short-term reference", the current picture is also marked as "used for short-term reference".
- Otherwise, the following applies.
 - Let `numShortTerm` be the total number of reference frames, complementary reference field pairs and non-paired reference fields for which at least one field is marked as "used for short-term reference". Let `numLongTerm` be the total number of reference frames, complementary reference field pairs and non-paired reference fields for which at least one field is marked as "used for long-term reference".
 - When `numShortTerm + numLongTerm` is equal to `Max(num_ref_frames, 1)`, the condition that `numShortTerm` is greater than 0 shall be fulfilled, and the short-term reference frame, complementary reference field pair or non-paired reference field that has the smallest value of `FrameNumWrap` is marked as "unused for reference". When it is a frame or a complementary field pair, both of its fields are also marked as "unused for reference".

8.2.5.4 Adaptive memory control decoded reference picture marking process

This process is invoked when `adaptive_ref_pic_marking_mode_flag` is equal to 1.

The `memory_management_control_operation` commands with values of 1 to 6 are processed in the order they occur in the bitstream after the current picture has been decoded. For each of these `memory_management_control_operation` commands, one of the processes specified in subclauses 8.2.5.4.1 to 8.2.5.4.5 is invoked depending on the value of `memory_management_control_operation`. The `memory_management_control_operation` command with value of 0 specifies the end of `memory_management_control_operation` commands.

Memory management control operations are applied to pictures as follows.

- If `field_pic_flag` is equal to 0, `memory_management_control_operation` commands are applied to the frames or complementary reference field pairs specified.
- Otherwise (`field_pic_flag` is equal to 1), `memory_management_control_operation` commands are applied to the individual reference fields specified.

8.2.5.4.1 Marking process of a short-term reference picture as "unused for reference"

This process is invoked when `memory_management_control_operation` is equal to 1.

Let `picNumX` be specified by

$$\text{picNumX} = \text{CurrPicNum} - (\text{difference_of_pic_nums_minus1} + 1). \quad (8-40)$$

Depending on `field_pic_flag` the value of `picNumX` is used to mark a short-term reference picture as "unused for reference" as follows.

- If `field_pic_flag` is equal to 0, the short-term reference frame or short-term complementary reference field pair specified by `picNumX` and both of its fields are marked as "unused for reference".
- Otherwise (`field_pic_flag` is equal to 1), the short-term reference field specified by `picNumX` is marked as "unused for reference". When that reference field is part of a reference frame or a complementary reference field pair, the

frame or complementary field pair is also marked as "unused for reference", but the marking of the other field is not changed.

8.2.5.4.2 Marking process of a long-term reference picture as “unused for reference”

This process is invoked when `memory_management_control_operation` is equal to 2.

Depending on `field_pic_flag` the value of `LongTermPicNum` is used to mark a long-term reference picture as “unused for reference” as follows.

- If `field_pic_flag` is equal to 0, the long-term reference frame or long-term complementary reference field pair having `LongTermPicNum` equal to `long_term_pic_num` and both of its fields are marked as “unused for reference”.
- Otherwise (`field_pic_flag` is equal to 1), the long-term reference field specified by `LongTermPicNum` equal to `long_term_pic_num` is marked as “unused for reference”. When that reference field is part of a reference frame or a complementary reference field pair, the frame or complementary field pair is also marked as "unused for reference", but the marking of the other field is not changed.

8.2.5.4.3 Assignment process of a LongTermFrameIdx to a short-term reference picture

This process is invoked when `memory_management_control_operation` is equal to 3.

Given the syntax element `difference_of_pic_nums_minus1`, the variable `picNumX` is obtained as specified in subclause 8.2.5.4.1. `picNumX` shall refer to a frame or complementary reference field pair or non-paired reference field marked as "used for short-term reference" and not marked as "non-existing".

When `LongTermFrameIdx` equal to `long_term_frame_idx` is already assigned to a long-term reference frame or a long-term complementary reference field pair, that frame or complementary field pair and both of its fields are marked as "unused for reference". When `LongTermFrameIdx` is already assigned to a non-paired reference field, and the field is not the complementary field of the picture specified by `picNumX`, that field is marked as “unused for reference”.

Depending on `field_pic_flag` the value of `LongTermFrameIdx` is used to mark a picture from "used for short-term reference" to "used for long-term reference" as follows.

- If `field_pic_flag` is equal to 0, the marking of the short-term reference frame or short-term complementary reference field pair specified by `picNumX` and both of its fields are changed from "used for short-term reference" to "used for long-term reference" and assigned `LongTermFrameIdx` equal to `long_term_frame_idx`.
- Otherwise (`field_pic_flag` is equal to 1), the marking of the short-term reference field specified by `picNumX` is changed from "used for short-term reference" to "used for long-term reference" and assigned `LongTermFrameIdx` equal to `long_term_frame_idx`. When the field is part of a reference frame or a complementary reference field pair, and the other field of the same reference frame or complementary reference field pair is also marked as "used for long-term reference", the reference frame or complementary reference field pair is also marked as "used for long-term reference" and assigned `LongTermFrameIdx` equal to `long_term_frame_idx`.

8.2.5.4.4 Decoding process for MaxLongTermFrameIdx

This process is invoked when `memory_management_control_operation` is equal to 4.

All pictures for which `LongTermFrameIdx` is greater than `max_long_term_frame_idx_plus1 - 1` and that are marked as "used for long-term reference" are marked as “unused for reference”.

The variable `MaxLongTermFrameIdx` is derived as follows.

- If `max_long_term_frame_idx_plus1` is equal to 0, `MaxLongTermFrameIdx` is set equal to “no long-term frame indices”.
- Otherwise (`max_long_term_frame_idx_plus1` is greater than 0), `MaxLongTermFrameIdx` is set equal to `max_long_term_frame_idx_plus1 - 1`.

NOTE – The `memory_management_control_operation` command equal to 4 can be used to mark long-term reference pictures as “unused for reference”. The frequency of transmitting `max_long_term_frame_idx_plus1` is not specified by this Recommendation | International Standard. However, the encoder should send a `memory_management_control_operation` command equal to 4 upon receiving an error message, such as an intra refresh request message.

8.2.5.4.4.1 Marking process of all reference pictures as “unused for reference” and setting MaxLongTermFrameIdx to “no long-term frame indices”

This process is invoked when `memory_management_control_operation` is equal to 5.

All reference pictures are marked as “unused for reference” and the variable MaxLongTermFrameIdx is set equal to “no long-term frame indices”.

8.2.5.4.5 Process for assigning a long-term frame index to the current picture

This process is invoked when memory_management_control_operation is equal to 6.

When a variable LongTermFrameIdx equal to long_term_frame_idx is already assigned to a long-term reference frame or a long-term complementary reference field pair, that frame or complementary field pair and both of its fields are marked as "unused for reference". When LongTermFrameIdx is already assigned to a non-paired reference field, and the field is not the complementary field of the current picture, that field is marked as “unused for reference”.

The current picture is marked as "used for long-term reference" and assigned LongTermFrameIdx equal to long_term_frame_idx.

When field_pic_flag is equal to 0, both its fields are also marked as "used for long-term reference" and assigned LongTermFrameIdx equal to long_term_frame_idx.

When field_pic_flag is equal to 1 and the current picture is the second field (in decoding order) of a complementary reference field pair, and the first field of the complementary reference field pair is also currently marked as "used for long-term reference", the complementary reference field pair is also marked as "used for long-term reference" and assigned LongTermFrameIdx equal to long_term_frame_idx.

After marking the current decoded reference picture, the total number of frames with at least one field marked as “used for reference”, plus the number of complementary field pairs with at least one field marked as “used for reference”, plus the number of non-paired fields marked as “used for reference” shall not be greater than Max(num_ref_frames, 1).

NOTE – Under some circumstances, the above statement may impose a constraint on the order in which a memory_management_control_operation syntax element equal to 6 can appear in the decoded reference picture marking syntax relative to a memory_management_control_operation syntax element equal to 1, 2, or 4.

8.3 Intra prediction process

This process is invoked for I and SI macroblock types.

Inputs to this process are constructed samples prior to the deblocking filter process and, for Intra_NxN prediction modes (where NxN is equal to 4x4 or 8x8), the values of IntraNxNPredMode from neighbouring macroblocks.

Outputs of this process are specified as follows.

- If the macroblock prediction mode is Intra_4x4 or Intra_8x8, the outputs are constructed luma samples prior to the deblocking filter process and (when chroma_format_idc is not equal to 0) chroma prediction samples of the macroblock pred_C, where C is equal to C_b and C_r.
- Otherwise, if mb_type is not equal to I_PCM, the outputs are luma prediction samples of the macroblock pred_L and (when chroma_format_idc is not equal to 0) chroma prediction samples of the macroblock pred_C, where C is equal to C_b and C_r.
- Otherwise (mb_type is equal to I_PCM), the outputs are constructed luma and (when chroma_format_idc is not equal to 0) chroma samples prior to the deblocking filter process.

The variable MvCnt is set equal to 0.

Depending on the value of mb_type the following applies.

- If mb_type is equal to I_PCM, the process specified in subclause 8.3.5 is invoked.
- Otherwise (mb_type is not equal to I_PCM), the following applies.
 - The decoding processes for Intra prediction modes are described for the luma component as follows.
 - If the macroblock prediction mode is equal to Intra_4x4, the specification in subclause 8.3.1 applies.
 - Otherwise, if the macroblock prediction mode is equal to Intra_8x8, the specification in subclause 8.3.2 applies.
 - Otherwise (the macroblock prediction mode is equal to Intra_16x16), the specification in subclause 8.3.3 applies.
 - The decoding processes for Intra prediction modes for the chroma components are described in subclause 8.3.4. This process is only invoked when chroma_format_idc is not equal to 0 (monochrome).

Samples used in the Intra prediction process are the sample values prior to alteration by any deblocking filter operation.

8.3.1 Intra_4x4 prediction process for luma samples

This process is invoked when the macroblock prediction mode is equal to Intra_4x4.

Inputs to this process are the values of Intra4x4PredMode (if available) or Intra8x8PredMode (if available) from neighbouring macroblocks or macroblock pairs.

The luma component of a macroblock consists of 16 blocks of 4x4 luma samples. These blocks are inverse scanned using the 4x4 luma block inverse scanning process as specified in subclause 6.4.3.

For all 4x4 luma blocks of the luma component of a macroblock with luma4x4BlkIdx = 0..15, the derivation process for the Intra4x4PredMode as specified in subclause 8.3.1.1 is invoked with luma4x4BlkIdx as well as Intra4x4PredMode and Intra8x8PredMode that are previously (in decoding order) derived for adjacent macroblocks as the input and the variable Intra4x4PredMode[luma4x4BlkIdx] as the output.

For each luma block of 4x4 samples indexed using luma4x4BlkIdx = 0..15,

1. The Intra_4x4 sample prediction process in subclause 8.3.1.2 is invoked with luma4x4BlkIdx and constructed samples prior (in decoding order) to the deblocking filter process from adjacent luma blocks as the input and the output are the Intra_4x4 luma prediction samples $\text{pred}_{4x4L}[x, y]$ with $x, y = 0..3$.
2. The position of the upper-left sample of a 4x4 luma block with index luma4x4BlkIdx inside the current macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with luma4x4BlkIdx as the input and the output being assigned to (xO, yO) and $x, y = 0..3$.

$$\text{pred}_{L}[xO + x, yO + y] = \text{pred}_{4x4L}[x, y] \quad (8-41)$$

3. The transform coefficient decoding process and picture construction process prior to deblocking filter process in subclause 8.5 is invoked with pred_{L} and luma4x4BlkIdx as the input and the constructed samples for the current 4x4 luma block S'_L as the output.

8.3.1.1 Derivation process for the Intra4x4PredMode

Inputs to this process are the index of the 4x4 luma block luma4x4BlkIdx and variable arrays Intra4x4PredMode (if available) and Intra8x8PredMode (if available) that are previously (in decoding order) derived for adjacent macroblocks.

Output of this process is the variable Intra4x4PredMode[luma4x4BlkIdx].

Table 8-2 specifies the values for Intra4x4PredMode[luma4x4BlkIdx] and the associated names.

Table 8-2 – Specification of Intra4x4PredMode[luma4x4BlkIdx] and associated names

Intra4x4PredMode[luma4x4BlkIdx]	Name of Intra4x4PredMode[luma4x4BlkIdx]
0	Intra_4x4_Vertical (prediction mode)
1	Intra_4x4_Horizontal (prediction mode)
2	Intra_4x4_DC (prediction mode)
3	Intra_4x4_Diagonal_Down_Left (prediction mode)
4	Intra_4x4_Diagonal_Down_Right (prediction mode)
5	Intra_4x4_Vertical_Right (prediction mode)
6	Intra_4x4_Horizontal_Down (prediction mode)
7	Intra_4x4_Vertical_Left (prediction mode)
8	Intra_4x4_Horizontal_Up (prediction mode)

Intra4x4PredMode[luma4x4BlkIdx] labelled 0, 1, 3, 4, 5, 6, 7, and 8 represent directions of predictions as illustrated in Figure 8-1.

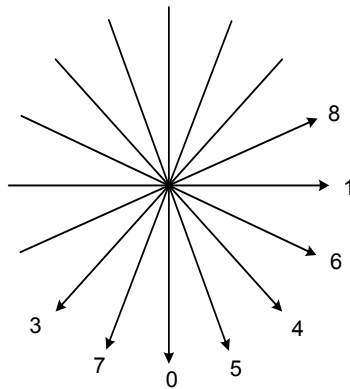


Figure 8-1 – Intra_4x4 prediction mode directions (informative)

Intra4x4PredMode[luma4x4BlkIdx] is derived as follows.

- The process specified in subclause 6.4.8.3 is invoked with luma4x4BlkIdx given as input and the output is assigned to mbAddrA, luma4x4BlkIdxA, mbAddrB, and luma4x4BlkIdxB.
- The variable dcPredModePredictedFlag is derived as follows.
 - If any of the following conditions are true, dcPredModePredictedFlag is set equal to 1
 - the macroblock with address mbAddrA is not available
 - the macroblock with address mbAddrB is not available
 - the macroblock with address mbAddrA is available and coded in Inter prediction mode and constrained_intra_pred_flag is equal to 1
 - the macroblock with address mbAddrB is available and coded in Inter prediction mode and constrained_intra_pred_flag is equal to 1
 - Otherwise, dcPredModePredictedFlag is set equal to 0.
- For N being either replaced by A or B, the variables intraMxMPredModeN are derived as follows.
 - If dcPredModePredictedFlag is equal to 1 or the macroblock with address mbAddrN is not coded in Intra_4x4 or Intra_8x8 macroblock prediction mode, intraMxMPredModeN is set equal to 2 (Intra_4x4_DC prediction mode).
 - Otherwise (dcPredModePredictedFlag is equal to 0 and (the macroblock with address mbAddrN is coded in Intra_4x4 macroblock prediction mode or the macroblock with address mbAddrN is coded in Intra_8x8 macroblock prediction mode)), the following applies.
 - If the macroblock with address mbAddrN is coded in Intra_4x4 macroblock mode, intraMxMPredModeN is set equal to Intra4x4PredMode[luma4x4BlkIdxN], where Intra4x4PredMode is the variable array assigned to the macroblock mbAddrN.
 - Otherwise (the macroblock with address mbAddrN is coded in Intra_8x8 macroblock mode), intraMxMPredModeN is set equal to Intra8x8PredMode[luma4x4BlkIdxN >> 2], where Intra8x8PredMode is the variable array assigned to the macroblock mbAddrN.
- Intra4x4PredMode[luma4x4BlkIdx] is derived by applying the following procedure.

$$\begin{aligned}
 & \text{predIntra4x4PredMode} = \text{Min}(\text{intraMxMPredModeA}, \text{intraMxMPredModeB}) \\
 & \text{if}(\text{prev_intra4x4_pred_mode_flag}[\text{luma4x4BlkIdx}]) \\
 & \quad \text{Intra4x4PredMode}[\text{luma4x4BlkIdx}] = \text{predIntra4x4PredMode} \\
 & \text{else} \\
 & \quad \text{if}(\text{rem_intra4x4_pred_mode}[\text{luma4x4BlkIdx}] < \text{predIntra4x4PredMode}) \\
 & \quad \quad \text{Intra4x4PredMode}[\text{luma4x4BlkIdx}] = \text{rem_intra4x4_pred_mode}[\text{luma4x4BlkIdx}] \\
 & \quad \text{else} \\
 & \quad \quad \text{Intra4x4PredMode}[\text{luma4x4BlkIdx}] = \text{rem_intra4x4_pred_mode}[\text{luma4x4BlkIdx}] + 1
 \end{aligned}
 \tag{8-42}$$

8.3.1.2 Intra_4x4 sample prediction

This process is invoked for each 4x4 luma block of a macroblock with prediction mode equal to Intra_4x4 followed by the transform decoding process and picture construction process prior to deblocking for each 4x4 luma block.

Input to this process is the index of a 4x4 luma block `luma4x4BlkIdx`.

Output of this process are the prediction samples `pred4x4L[x, y]`, with $x, y = 0..3$ for the 4x4 luma block with index `luma4x4BlkIdx`.

The position of the upper-left sample of a 4x4 luma block with index `luma4x4BlkIdx` inside the current macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with `luma4x4BlkIdx` as the input and the output being assigned to (xO, yO) .

The 13 neighbouring samples $p[x, y]$ that are constructed luma samples prior to the deblocking filter process, with $x = -1, y = -1..3$ and $x = 0..7, y = -1$, are derived as follows.

- The luma location (xN, yN) is specified by

$$xN = xO + x \quad (8-43)$$

$$yN = yO + y \quad (8-44)$$

- The derivation process for neighbouring locations in subclause 6.4.9 is invoked for luma locations with (xN, yN) as input and `mbAddrN` and (xW, yW) as output.
- Each sample $p[x, y]$ with $x = -1, y = -1..3$ and $x = 0..7, y = -1$ is derived as follows.
 - If any of the following conditions is true, the sample $p[x, y]$ is marked as “not available for Intra_4x4 prediction”
 - `mbAddrN` is not available,
 - the macroblock `mbAddrN` is coded in Inter prediction mode and `constrained_intra_pred_flag` is equal to 1.
 - the macroblock `mbAddrN` has `mb_type` equal to SI and `constrained_intra_pred_flag` is equal to 1 and the current macroblock does not have `mb_type` equal to SI.
 - x is greater than 3 and `luma4x4BlkIdx` is equal to 3 or 11
 - Otherwise, the sample $p[x, y]$ is marked as “available for Intra_4x4 prediction” and the luma sample at luma location (xW, yW) inside the macroblock `mbAddrN` is assigned to $p[x, y]$.

When samples $p[x, -1]$, with $x = 4..7$ are marked as “not available for Intra_4x4 prediction,” and the sample $p[3, -1]$ is marked as “available for Intra_4x4 prediction,” the sample value of $p[3, -1]$ is substituted for sample values $p[x, -1]$, with $x = 4..7$ and samples $p[x, -1]$, with $x = 4..7$ are marked as “available for Intra_4x4 prediction”.

NOTE – Each block is assumed to be constructed into a picture array prior to decoding of the next block.

Depending on `Intra4x4PredMode[luma4x4BlkIdx]`, one of the Intra_4x4 prediction modes specified in subclauses 8.3.1.2.1 to 8.3.1.2.9 is invoked.

8.3.1.2.1 Specification of Intra_4x4_Veritical prediction mode

This Intra_4x4 prediction mode is invoked when `Intra4x4PredMode[luma4x4BlkIdx]` is equal to 0.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..3$ are marked as “available for Intra_4x4 prediction”.

The values of the prediction samples `pred4x4L[x, y]`, with $x, y = 0..3$ are derived by

$$\text{pred4x4L}[x, y] = p[x, -1], \text{ with } x, y = 0..3 \quad (8-45)$$

8.3.1.2.2 Specification of Intra_4x4_Horizontal prediction mode

This Intra_4x4 prediction mode is invoked when `Intra4x4PredMode[luma4x4BlkIdx]` is equal to 1.

This mode shall be used only when the samples $p[-1, y]$, with $y = 0..3$ are marked as “available for Intra_4x4 prediction”.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived by

$$\text{pred4x4}_L[x, y] = p[-1, y], \text{ with } x, y = 0..3 \quad (8-46)$$

8.3.1.2.3 Specification of Intra_4x4_DC prediction mode

This Intra_4x4 prediction mode is invoked when $\text{Intra4x4PredMode}[\text{luma4x4BlkIdx}]$ is equal to 2.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

- If all samples $p[x, -1]$, with $x = 0..3$ and $p[-1, y]$, with $y = 0..3$ are marked as “available for Intra_4x4 prediction”, the values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived by

$$\text{pred4x4}_L[x, y] = (p[0, -1] + p[1, -1] + p[2, -1] + p[3, -1] + p[-1, 0] + p[-1, 1] + p[-1, 2] + p[-1, 3] + 4) \gg 3 \quad (8-47)$$

- Otherwise, if any samples $p[x, -1]$, with $x = 0..3$ are marked as “not available for Intra_4x4 prediction” and all samples $p[-1, y]$, with $y = 0..3$ are marked as “available for Intra_4x4 prediction”, the values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived by

$$\text{pred4x4}_L[x, y] = (p[-1, 0] + p[-1, 1] + p[-1, 2] + p[-1, 3] + 2) \gg 2 \quad (8-48)$$

- Otherwise, if any samples $p[-1, y]$, with $y = 0..3$ are marked as “not available for Intra_4x4 prediction” and all samples $p[x, -1]$, with $x = 0..3$ are marked as “available for Intra_4x4 prediction”, the values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived by

$$\text{pred4x4}_L[x, y] = (p[0, -1] + p[1, -1] + p[2, -1] + p[3, -1] + 2) \gg 2 \quad (8-49)$$

- Otherwise (some samples $p[x, -1]$, with $x = 0..3$ and some samples $p[-1, y]$, with $y = 0..3$ are marked as “not available for Intra_4x4 prediction”), the values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived by

$$\text{pred4x4}_L[x, y] = (1 \ll (\text{BitDepth}_Y - 1)) \quad (8-50)$$

NOTE – A 4x4 luma block can always be predicted using this mode.

8.3.1.2.4 Specification of Intra_4x4_Diagonal_Down_Left prediction mode

This Intra_4x4 prediction mode is invoked when $\text{Intra4x4PredMode}[\text{luma4x4BlkIdx}]$ is equal to 3.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..7$ are marked as “available for Intra_4x4 prediction”.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

- If x is equal to 3 and y is equal to 3,

$$\text{pred4x4}_L[x, y] = (p[6, -1] + 3 * p[7, -1] + 2) \gg 2 \quad (8-51)$$

- Otherwise (x is not equal to 3 or y is not equal to 3),

$$\text{pred4x4}_L[x, y] = (p[x + y, -1] + 2 * p[x + y + 1, -1] + p[x + y + 2, -1] + 2) \gg 2 \quad (8-52)$$

8.3.1.2.5 Specification of Intra_4x4_Diagonal_Down_Right prediction mode

This Intra_4x4 prediction mode is invoked when $\text{Intra4x4PredMode}[\text{luma4x4BlkIdx}]$ is equal to 4.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..3$ and $p[-1, y]$ with $y = -1..3$ are marked as “available for Intra_4x4 prediction”.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

- If x is greater than y ,

$$\text{pred4x4}_L[x, y] = (p[x - y - 2, -1] + 2 * p[x - y - 1, -1] + p[x - y, -1] + 2) \gg 2 \quad (8-53)$$

– Otherwise if x is less than y,

$$\text{pred4x4}_L[x, y] = (p[-1, y - x - 2] + 2 * p[-1, y - x - 1] + p[-1, y - x] + 2) \gg 2 \quad (8-54)$$

– Otherwise (x is equal to y),

$$\text{pred4x4}_L[x, y] = (p[0, -1] + 2 * p[-1, -1] + p[-1, 0] + 2) \gg 2 \quad (8-55)$$

8.3.1.2.6 Specification of Intra_4x4_Vertical_Right prediction mode

This Intra_4x4 prediction mode is invoked when Intra4x4PredMode[luma4x4BlkIdx] is equal to 5.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..3$ and $p[-1, y]$ with $y = -1..3$ are marked as “available for Intra_4x4 prediction”.

Let the variable zVR be set equal to $2 * x - y$.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

– If zVR is equal to 0, 2, 4, or 6,

$$\text{pred4x4}_L[x, y] = (p[x - (y \gg 1) - 1, -1] + p[x - (y \gg 1), -1] + 1) \gg 1 \quad (8-56)$$

– Otherwise, if zVR is equal to 1, 3, or 5,

$$\text{pred4x4}_L[x, y] = (p[x - (y \gg 1) - 2, -1] + 2 * p[x - (y \gg 1) - 1, -1] + p[x - (y \gg 1), -1] + 2) \gg 2 \quad (8-57)$$

– Otherwise, if zVR is equal to -1,

$$\text{pred4x4}_L[x, y] = (p[-1, 0] + 2 * p[-1, -1] + p[0, -1] + 2) \gg 2 \quad (8-58)$$

– Otherwise (zVR is equal to -2 or -3),

$$\text{pred4x4}_L[x, y] = (p[-1, y - 1] + 2 * p[-1, y - 2] + p[-1, y - 3] + 2) \gg 2 \quad (8-59)$$

8.3.1.2.7 Specification of Intra_4x4_Horizontal_Down prediction mode

This Intra_4x4 prediction mode is invoked when Intra4x4PredMode[luma4x4BlkIdx] is equal to 6.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..3$ and $p[-1, y]$ with $y = -1..3$ are marked as “available for Intra_4x4 prediction”.

Let the variable zHD be set equal to $2 * y - x$.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

– If zHD is equal to 0, 2, 4, or 6,

$$\text{pred4x4}_L[x, y] = (p[-1, y - (x \gg 1) - 1] + p[-1, y - (x \gg 1)] + 1) \gg 1 \quad (8-60)$$

– Otherwise, if zHD is equal to 1, 3, or 5,

$$\text{pred4x4}_L[x, y] = (p[-1, y - (x \gg 1) - 2] + 2 * p[-1, y - (x \gg 1) - 1] + p[-1, y - (x \gg 1)] + 2) \gg 2 \quad (8-61)$$

– Otherwise, if zHD is equal to -1,

$$\text{pred4x4}_L[x, y] = (p[-1, 0] + 2 * p[-1, -1] + p[0, -1] + 2) \gg 2 \quad (8-62)$$

– Otherwise (zHD is equal to -2 or -3),

$$\text{pred4x4}_L[x, y] = (p[x - 1, -1] + 2 * p[x - 2, -1] + p[x - 3, -1] + 2) \gg 2 \quad (8-63)$$

8.3.1.2.8 Specification of Intra_4x4_Vertical_Left prediction mode

This Intra_4x4 prediction mode is invoked when Intra4x4PredMode[luma4x4BlkIdx] is equal to 7.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..7$ are marked as “available for Intra_4x4 prediction”.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows.

- If y is equal to 0 or 2,

$$\text{pred4x4}_L[x, y] = (p[x + (y \gg 1), -1] + p[x + (y \gg 1) + 1, -1] + 1) \gg 1 \quad (8-64)$$

- Otherwise (y is equal to 1 or 3),

$$\text{pred4x4}_L[x, y] = (p[x + (y \gg 1), -1] + 2 * p[x + (y \gg 1) + 1, -1] + p[x + (y \gg 1) + 2, -1] + 2) \gg 2 \quad (8-65)$$

8.3.1.2.9 Specification of Intra_4x4_Horizontal_Up prediction mode

This Intra_4x4 prediction mode is invoked when Intra4x4PredMode[luma4x4BlkIdx] is equal to 8.

This mode shall be used only when the samples $p[-1, y]$ with $y = 0..3$ are marked as “available for Intra_4x4 prediction”.

Let the variable zHU be set equal to $x + 2 * y$.

The values of the prediction samples $\text{pred4x4}_L[x, y]$, with $x, y = 0..3$ are derived as follows:

- If zHU is equal to 0, 2, or 4

$$\text{pred4x4}_L[x, y] = (p[-1, y + (x \gg 1)] + p[-1, y + (x \gg 1) + 1] + 1) \gg 1 \quad (8-66)$$

- Otherwise, if zHU is equal to 1 or 3

$$\text{pred4x4}_L[x, y] = (p[-1, y + (x \gg 1)] + 2 * p[-1, y + (x \gg 1) + 1] + p[-1, y + (x \gg 1) + 2] + 2) \gg 2 \quad (8-67)$$

- Otherwise, if zHU is equal to 5,

$$\text{pred4x4}_L[x, y] = (p[-1, 2] + 3 * p[-1, 3] + 2) \gg 2 \quad (8-68)$$

- Otherwise (zHU is greater than 5),

$$\text{pred4x4}_L[x, y] = p[-1, 3] \quad (8-69)$$

8.3.2 Intra_8x8 prediction process for luma samples

This process is invoked when the macroblock prediction mode is equal to Intra_8x8.

Inputs to this process are the values of Intra4x4PredMode (if available) or Intra8x8PredMode (if available) from the neighbouring macroblocks or macroblock pairs.

Outputs of this process are 8x8 luma sample arrays as part of the 16x16 luma array of prediction samples of the macroblock pred_L .

The luma component of a macroblock consists of 4 blocks of 8x8 luma samples. These blocks are inverse scanned using the inverse 8x8 luma block scanning process as specified in subclause 6.4.4.

For all 8x8 luma blocks of the luma component of a macroblock with $\text{luma8x8BlkIdx} = 0..3$, the derivation process for Intra8x8PredMode as specified in subclause 8.3.2.1 is invoked with luma8x8BlkIdx as well as Intra4x4PredMode and

Intra8x8PredMode that are previously (in decoding order) derived for adjacent macroblocks as the input and the variable Intra8x8PredMode[luma8x8BlkIdx] as the output.

For each luma block of 8x8 samples indexed using luma8x8BlkIdx = 0..3, the following applies.

- The Intra_8x8 sample prediction process in subclause 8.3.2.2 is invoked with luma8x8BlkIdx and constructed samples prior (in decoding order) to the deblocking filter process from adjacent luma blocks as the input and the output are the Intra_8x8 luma prediction samples pred8x8L[x, y] with x, y = 0..7.
- The position of the upper-left sample of an 8x8 luma block with index luma8x8BlkIdx inside the current macroblock is derived by invoking the inverse 8x8 luma block scanning process in subclause 6.4.4 with luma8x8BlkIdx as the input and the output being assigned to (xO, yO) and x, y = 0..7.

$$\text{pred}_L[xO + x, yO + y] = \text{pred8x8}_L[x, y] \quad (8-70)$$

- The transform coefficient decoding process and picture construction process prior to deblocking filter process in subclause 8.5 is invoked with pred_L and luma8x8BlkIdx as the input and the constructed samples for the current 8x8 luma block S'_L as the output.

8.3.2.1 Derivation process for Intra8x8PredMode

Inputs to this process are the index of the 8x8 luma block luma8x8BlkIdx and variable arrays Intra4x4PredMode (if available) and Intra8x8PredMode (if available) that are previously (in decoding order) derived for adjacent macroblocks.

Output of this process is the variable Intra8x8PredMode[luma8x8BlkIdx].

Table 8-3 specifies the values for Intra8x8PredMode[luma8x8BlkIdx] and the associated mnemonic names.

Table 8-3 – Specification of Intra8x8PredMode[luma8x8BlkIdx] and associated names

Intra8x8PredMode[luma8x8BlkIdx]	Name of Intra8x8PredMode[luma8x8BlkIdx]
0	Intra_8x8_Vertical (prediction mode)
1	Intra_8x8_Horizontal (prediction mode)
2	Intra_8x8_DC (prediction mode)
3	Intra_8x8_Diagonal_Down_Left (prediction mode)
4	Intra_8x8_Diagonal_Down_Right (prediction mode)
5	Intra_8x8_Vertical_Right (prediction mode)
6	Intra_8x8_Horizontal_Down (prediction mode)
7	Intra_8x8_Vertical_Left (prediction mode)
8	Intra_8x8_Horizontal_Up (prediction mode)

Intra8x8PredMode[luma8x8BlkIdx] is derived as follows.

- The process specified in subclause 6.4.8.2 is invoked with luma8x8BlkIdx given as input and the output is assigned to mbAddrA, luma8x8BlkIdxA, mbAddrB, and luma8x8BlkIdxB.
- The variable dcPredModePredictedFlag is derived as follows.
 - If any of the following conditions are true, dcPredModePredictedFlag is set equal to 1
 - the macroblock with address mbAddrA is not available
 - the macroblock with address mbAddrB is not available
 - the macroblock with address mbAddrA is available and coded in Inter prediction mode and constrained_intra_pred_flag is equal to 1

- the macroblock with address mbAddrB is available and coded in Inter prediction mode and constrained_intra_pred_flag is equal to 1
- Otherwise, dcPredModePredictedFlag is set equal to 0.
- For N being either replaced by A or B, the variables intraMxMPredModeN are derived as follows.
 - If dcPredModePredictedFlag is equal to 1 or (the macroblock with address mbAddrN is not coded in Intra_4x4 macroblock prediction mode and the macroblock with address mbAddrN is not coded in Intra_8x8 macroblock prediction mode), intraMxMPredModeN is set equal to 2 (Intra_8x8_DC prediction mode).
 - Otherwise (dcPredModePredictedFlag is equal to 0 and (the macroblock with address mbAddrN is coded in Intra_4x4 macroblock prediction mode or the macroblock with address mbAddrN is coded in Intra_8x8 macroblock prediction mode)), the following applies.
 - If the macroblock with address mbAddrN is coded in Intra_8x8 macroblock mode, intraMxMPredModeN is set equal to Intra8x8PredMode[luma8x8BlkIdxN], where Intra8x8PredMode is the variable array assigned to the macroblock mbAddrN.
 - Otherwise (the macroblock with address mbAddrN is coded in Intra_4x4 macroblock mode), intraMxMPredModeN is derived by the following procedure, where Intra4x4PredMode is the variable array assigned to the macroblock mbAddrN.

$$\text{intraMxMPredModeN} = \text{Intra4x4PredMode}[\text{luma8x8BlkIdxN} * 4 + n] \quad (8-71)$$

where the variable n is derived as follows

- If N is equal to A, depending on the variable MbaffFrameFlag, the variable luma8x8BlkIdx, the current macroblock, and the macroblock mbAddrN, the following applies.
 - If MbaffFrameFlag is equal to 1, the current macroblock is a frame coded macroblock, the macroblock mbAddrN is a field coded macroblock, and luma8x8BlkIdx is equal to 2, n is set equal to 3.
 - Otherwise (MbaffFrameFlag is equal to 0 or the current macroblock is a field coded macroblock or the macroblock mbAddrN is a frame coded macroblock or luma8x8BlkIdx is not equal to 2), n is set equal to 1.
- Otherwise (N is equal to B), n is set equal to 2.
- Finally, given intraMxMPredModeA and intraMxMPredModeB, the variable Intra8x8PredMode[luma8x8BlkIdx] is derived by applying the following procedure.

$$\begin{aligned}
 &\text{predIntra8x8PredMode} = \text{Min}(\text{intraMxMPredModeA}, \text{intraMxMPredModeB}) \\
 &\text{if}(\text{prev_intra8x8_pred_mode_flag}[\text{luma8x8BlkIdx}]) \\
 &\quad \text{Intra8x8PredMode}[\text{luma8x8BlkIdx}] = \text{predIntra8x8PredMode} \\
 &\text{else} \\
 &\quad \text{if}(\text{rem_intra8x8_pred_mode}[\text{luma8x8BlkIdx}] < \text{predIntra8x8PredMode}) \\
 &\quad \quad \text{Intra8x8PredMode}[\text{luma8x8BlkIdx}] = \text{rem_intra8x8_pred_mode}[\text{luma8x8BlkIdx}] \\
 &\quad \text{else} \\
 &\quad \quad \text{Intra8x8PredMode}[\text{luma8x8BlkIdx}] = \text{rem_intra8x8_pred_mode}[\text{luma8x8BlkIdx}] + 1
 \end{aligned} \quad (8-72)$$

8.3.2.2 Intra_8x8 sample prediction

This process is invoked for each 8x8 luma block of a macroblock with prediction mode equal to Intra_8x8 followed by the transform decoding process and picture construction process prior to deblocking for each 8x8 luma block.

Input to this process is the index of an 8x8 luma block luma8x8BlkIdx.

Output of this process are the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ for the 8x8 luma block with index luma8x8BlkIdx.

The position of the upper-left sample of an 8x8 luma block with index luma8x8BlkIdx inside the current macroblock is derived by invoking the inverse 8x8 luma block scanning process in subclause 6.4.4 with luma8x8BlkIdx as the input and the output being assigned to (xO, yO).

The 25 neighbouring samples $p[x, y]$ that are constructed luma samples prior to the deblocking filter process, with $x = -1, y = -1..7$ and $x = 0..15, y = -1$, are derived as follows.

- The luma location (xN, yN) is specified by

$$xN = xO + x \quad (8-73)$$

$$yN = yO + y \quad (8-74)$$

- The derivation process for neighbouring locations in subclause 6.4.9 is invoked for luma locations with (xN, yN) as input and mbAddrN and (xW, yW) as output.
- Each sample p[x, y] with x = -1, y = -1..7 and x = 0..15, y = -1 is derived as follows.
 - If any of the following conditions is true, the sample p[x, y] is marked as “not available for Intra_8x8 prediction”
 - mbAddrN is not available,
 - the macroblock mbAddrN is coded in Inter prediction mode and constrained_intra_pred_flag is equal to 1,
 - Otherwise, the sample p[x, y] is marked as “available for Intra_8x8 prediction” and the luma sample at luma location (xW, yW) inside the macroblock mbAddrN is assigned to p[x, y].

When samples p[x, -1], with x = 8..15 are marked as “not available for Intra_8x8 prediction,” and the sample p[7, -1] is marked as “available for Intra_8x8 prediction,” the sample value of p[7, -1] is substituted for sample values p[x, -1], with x = 8..15 and samples p[x, -1], with x = 8..15 are marked as “available for Intra_8x8 prediction”.

NOTE – Each block is assumed to be constructed into a picture array prior to decoding of the next block.

The reference sample filtering process for Intra_8x8 sample prediction in subclause 8.3.2.2.1 is invoked with the samples p[x, y] with x = -1, y = -1..7 and x = 0..15, y = -1 (if available) as input and p'[x, y] with x = -1, y = -1..7 and x = 0..15, y = -1 as output.

Depending on Intra8x8PredMode[luma8x8BlkIdx], one of the Intra_8x8 prediction modes specified in subclauses 8.3.2.2.2 to 8.3.2.2.10 is invoked.

8.3.2.2.1 Reference sample filtering process for Intra_8x8 sample prediction

Inputs to this process are the reference samples p[x, y] with x = -1, y = -1..7 and x = 0..15, y = -1 (if available) for Intra_8x8 sample prediction.

Outputs of this process are the filtered reference samples p'[x, y] with x = -1, y = -1..7 and x = 0..15, y = -1 for Intra_8x8 sample prediction.

When all samples p[x, -1] with x = 0..7 are marked as “available for Intra_8x8 prediction”, the following applies.

- The value of p'[0, -1] is derived as follows.
 - If p[-1, -1] is marked as “available for Intra_8x8 prediction”, p'[0, -1] is derived by

$$p'[0, -1] = (p[-1, -1] + 2 * p[0, -1] + p[1, -1] + 2) \gg 2 \quad (8-75)$$

- Otherwise (p[-1, -1] is marked as “not available for Intra_8x8 prediction”), p'[0, -1] is derived by

$$p'[0, -1] = (3 * p[0, -1] + p[1, -1] + 2) \gg 2 \quad (8-76)$$

- The values of p'[x, -1], with x = 1..7 are derived by

$$p'[x, -1] = (p[x-1, -1] + 2 * p[x, -1] + p[x+1, -1] + 2) \gg 2 \quad (8-77)$$

When all samples p[x, -1] with x = 7..15 are marked as “available for Intra_8x8 prediction”, the following applies.

- The values of p'[x, -1], with x = 8..14 are derived by

$$p'[x, -1] = (p[x-1, -1] + 2 * p[x, -1] + p[x+1, -1] + 2) \gg 2 \quad (8-78)$$

- The value of p'[15, -1] is derived by

$$p'[15, -1] = (p[14, -1] + 3 * p[15, -1] + 2) \gg 2 \quad (8-79)$$

When the sample $p[-1, -1]$ is marked as “available for Intra_8x8 prediction”, the value of $p'[-1, -1]$ is derived as follows.

- If the sample $p[0, -1]$ is marked as “not available for Intra_8x8 prediction” or the sample $p[-1, 0]$ is marked as “not available for Intra_8x8 prediction”, the following applies.

- If the sample $p[0, -1]$ is marked as “available for Intra_8x8 prediction”, $p'[-1, -1]$ is derived by

$$p'[-1, -1] = (3 * p[-1, -1] + p[0, -1] + 2) \gg 2 \quad (8-80)$$

- Otherwise (the sample $p[0, -1]$ is marked as “not available for Intra_8x8 prediction” and the sample $p[-1, 0]$ is marked as “available for Intra_8x8 prediction”), $p'[-1, -1]$ is derived by

$$p'[-1, -1] = (3 * p[-1, -1] + p[-1, 0] + 2) \gg 2 \quad (8-81)$$

- Otherwise (the sample $p[0, -1]$ is marked as “available for Intra_8x8 prediction” and the sample $p[-1, 0]$ is marked as “available for Intra_8x8 prediction”), $p'[-1, -1]$ is derived by

$$p'[-1, -1] = (p[0, -1] + 2 * p[-1, -1] + p[-1, 0] + 2) \gg 2 \quad (8-82)$$

When all samples $p[-1, y]$ with $y = 0..7$ are marked as “available for Intra_8x8 prediction”, the following applies.

- The value of $p'[-1, 0]$ is derived as follows.

- If $p[-1, -1]$ is marked as “available for Intra_8x8 prediction”, $p'[-1, 0]$ is derived by

$$p'[-1, 0] = (p[-1, -1] + 2 * p[-1, 0] + p[-1, 1] + 2) \gg 2 \quad (8-83)$$

- Otherwise (if $p[-1, -1]$ is marked as “not available for Intra_8x8 prediction”), $p'[-1, 0]$ is derived by

$$p'[-1, 0] = (3 * p[-1, 0] + p[-1, 1] + 2) \gg 2 \quad (8-84)$$

- The values of $p'[-1, y]$, with $y = 1..6$ are derived by

$$p'[-1, y] = (p[-1, y-1] + 2 * p[-1, y] + p[-1, y+1] + 2) \gg 2 \quad (8-85)$$

- The value of $p'[-1, 7]$ is derived by

$$p'[-1, 7] = (p[-1, 6] + 3 * p[-1, 7] + 2) \gg 2 \quad (8-86)$$

8.3.2.2.2 Specification of Intra_8x8_Vertical prediction mode

This Intra_8x8 prediction mode is invoked when $\text{Intra8x8PredMode}[\text{luma8x8BlkIdx}]$ is equal to 0.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..7$ are marked as “available for Intra_8x8 prediction”.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = p'[x, -1], \text{ with } x, y = 0..7 \quad (8-87)$$

8.3.2.2.3 Specification of Intra_8x8_Horizontal prediction mode

This Intra_8x8 prediction mode is invoked when $\text{Intra8x8PredMode}[\text{luma8x8BlkIdx}]$ is equal to 1.

This mode shall be used only when the samples $p[-1, y]$, with $y = 0..7$ are marked as “available for Intra_8x8 prediction”.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = p'[-1, y], \text{ with } x, y = 0..7 \quad (8-88)$$

8.3.2.2.4 Specification of Intra_8x8_DC prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 2.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived as follows.

- If all samples $p[x, -1]$, with $x = 0..7$ and $p[-1, y]$, with $y = 0..7$ are marked as “available for Intra_8x8 prediction,” the values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = \left(\sum_{x'=0}^7 p'[x', -1] + \sum_{y'=0}^7 p'[-1, y'] + 8 \right) \gg 4 \quad (8-89)$$

- Otherwise, if any samples $p[x, -1]$, with $x = 0..7$ are marked as “not available for Intra_8x8 prediction” and all samples $p[-1, y]$, with $y = 0..7$ are marked as “available for Intra_8x8 prediction”, the values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = \left(\sum_{y'=0}^7 p'[-1, y'] + 4 \right) \gg 3 \quad (8-90)$$

- Otherwise, if any samples $p[-1, y]$, with $y = 0..7$ are marked as “not available for Intra_8x8 prediction” and all samples $p[x, -1]$, with $x = 0..7$ are marked as “available for Intra_8x8 prediction”, the values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = \left(\sum_{x'=0}^7 p'[x', -1] + 4 \right) \gg 3 \quad (8-91)$$

- Otherwise (some samples $p[x, -1]$, with $x = 0..7$ and some samples $p[-1, y]$, with $y = 0..7$ are marked as “not available for Intra_8x8 prediction”), the values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived by

$$\text{pred8x8}_L[x, y] = (1 \ll (\text{BitDepth}_Y - 1)) \quad (8-92)$$

NOTE – An 8x8 luma block can always be predicted using this mode.

8.3.2.2.5 Specification of Intra_8x8_Diagonal_Down_Left prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 3.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..15$ are marked as “available for Intra_8x8 prediction”.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived as follows.

- If x is equal to 7 and y is equal to 7,

$$\text{pred8x8}_L[x, y] = (p[14, -1] + 3 * p[15, -1] + 2) \gg 2 \quad (8-93)$$

- Otherwise (x is not equal to 7 or y is not equal to 7),

$$\text{pred8x8}_L[x, y] = (p[x + y, -1] + 2 * p[x + y + 1, -1] + p[x + y + 2, -1] + 2) \gg 2 \quad (8-94)$$

8.3.2.2.6 Specification of Intra_8x8_Diagonal_Down_Right prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 4.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..7$ and $p[-1, y]$ with $y = -1..7$ are marked as “available for Intra_8x8 prediction”.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived as follows.

- If x is greater than y ,

$$\text{pred8x8}_L[x, y] = (p[x - y - 2, -1] + 2 * p[x - y - 1, -1] + p[x - y, -1] + 2) \gg 2 \quad (8-95)$$

- Otherwise if x is less than y,

$$\text{pred8x8}_L[x, y] = (p'[-1, y - x - 2] + 2 * p'[-1, y - x - 1] + p'[-1, y - x] + 2) \gg 2 \quad (8-96)$$

- Otherwise (x is equal to y),

$$\text{pred8x8}_L[x, y] = (p'[0, -1] + 2 * p'[-1, -1] + p'[-1, 0] + 2) \gg 2 \quad (8-97)$$

8.3.2.2.7 Specification of Intra_8x8_Vertical_Right prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 5.

This mode shall be used only when the samples p[x, -1] with x = 0..7 and p[-1, y] with y = -1..7 are marked as “available for Intra_8x8 prediction”.

Let the variable zVR be set equal to 2 * x - y.

The values of the prediction samples pred8x8_L[x, y], with x, y = 0..7 are derived as follows.

- If zVR is equal to 0, 2, 4, 6, 8, 10, 12, or 14

$$\text{pred8x8}_L[x, y] = (p'[x - (y \gg 1) - 1, -1] + p'[x - (y \gg 1), -1] + 1) \gg 1 \quad (8-98)$$

- Otherwise, if zVR is equal to 1, 3, 5, 7, 9, 11, or 13

$$\text{pred8x8}_L[x, y] = (p'[x - (y \gg 1) - 2, -1] + 2 * p'[x - (y \gg 1) - 1, -1] + p'[x - (y \gg 1), -1] + 2) \gg 2 \quad (8-99)$$

- Otherwise, if zVR is equal to -1,

$$\text{pred8x8}_L[x, y] = (p'[-1, 0] + 2 * p'[-1, -1] + p'[0, -1] + 2) \gg 2 \quad (8-100)$$

- Otherwise (zVR is equal to -2, -3, -4, -5, -6, or -7),

$$\text{pred8x8}_L[x, y] = (p'[-1, y - 2*x - 1] + 2 * p'[-1, y - 2*x - 2] + p'[-1, y - 2*x - 3] + 2) \gg 2 \quad (8-101)$$

8.3.2.2.8 Specification of Intra_8x8_Horizontal_Down prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 6.

This mode shall be used only when the samples p[x, -1] with x = 0..7 and p[-1, y] with y = -1..7 are marked as “available for Intra_8x8 prediction”.

Let the variable zHD be set equal to 2 * y - x.

The values of the prediction samples pred8x8_L[x, y], with x, y = 0..7 are derived as follows.

- If zHD is equal to 0, 2, 4, 6, 8, 10, 12, or 14

$$\text{pred8x8}_L[x, y] = (p'[-1, y - (x \gg 1) - 1] + p'[-1, y - (x \gg 1)] + 1) \gg 1 \quad (8-102)$$

- Otherwise, if zHD is equal to 1, 3, 5, 7, 9, 11, or 13

$$\text{pred8x8}_L[x, y] = (p'[-1, y - (x \gg 1) - 2] + 2 * p'[-1, y - (x \gg 1) - 1] + p'[-1, y - (x \gg 1)] + 2) \gg 2 \quad (8-103)$$

- Otherwise, if zHD is equal to -1,

$$\text{pred8x8}_L[x, y] = (p'[-1, 0] + 2 * p'[-1, -1] + p'[0, -1] + 2) \gg 2 \quad (8-104)$$

- Otherwise (zHD is equal to -2, -3, -4, -5, -6, -7),

$$\text{pred8x8}_L[x, y] = (p'[x - 2*y - 1, -1] + 2 * p'[x - 2*y - 2, -1] + p'[x - 2*y - 3, -1] + 2) \gg 2 \quad (8-105)$$

8.3.2.2.9 Specification of Intra_8x8_Vertical_Left prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 7.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..15$ are marked as “available for Intra_8x8 prediction”.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived as follows.

- If y is equal to 0, 2, 4 or 6

$$\text{pred8x8}_L[x, y] = (p'[x + (y \gg 1), -1] + p'[x + (y \gg 1) + 1, -1] + 1) \gg 1 \quad (8-106)$$

- Otherwise (y is equal to 1, 3, 5, 7),

$$\text{pred8x8}_L[x, y] = (p'[x + (y \gg 1), -1] + 2 * p'[x + (y \gg 1) + 1, -1] + p'[x + (y \gg 1) + 2, -1] + 2) \gg 2 \quad (8-107)$$

8.3.2.2.10 Specification of Intra_8x8_Horizontal_Up prediction mode

This Intra_8x8 prediction mode is invoked when Intra8x8PredMode[luma8x8BlkIdx] is equal to 8.

This mode shall be used only when the samples $p[-1, y]$ with $y = 0..7$ are marked as “available for Intra_8x8 prediction”.

Let the variable zHU be set equal to $x + 2 * y$.

The values of the prediction samples $\text{pred8x8}_L[x, y]$, with $x, y = 0..7$ are derived as follows:

- If zHU is equal to 0, 2, 4, 6, 8, 10, or 12

$$\text{pred8x8}_L[x, y] = (p'[-1, y + (x \gg 1)] + p'[-1, y + (x \gg 1) + 1] + 1) \gg 1 \quad (8-108)$$

- Otherwise, if zHU is equal to 1, 3, 5, 7, 9, or 11

$$\text{pred8x8}_L[x, y] = (p'[-1, y + (x \gg 1)] + 2 * p'[-1, y + (x \gg 1) + 1] + p'[-1, y + (x \gg 1) + 2] + 2) \gg 2 \quad (8-109)$$

- Otherwise, if zHU is equal to 13,

$$\text{pred8x8}_L[x, y] = (p'[-1, 6] + 3 * p'[-1, 7] + 2) \gg 2 \quad (8-110)$$

- Otherwise (zHU is greater than 13),

$$\text{pred8x8}_L[x, y] = p'[-1, 7] \quad (8-111)$$

8.3.3 Intra_16x16 prediction process for luma samples

This process is invoked when the macroblock prediction mode is equal to Intra_16x16. It specifies how the Intra prediction luma samples for the current macroblock are derived.

Outputs of this process are Intra prediction luma samples for the current macroblock $\text{pred}_L[x, y]$.

The 33 neighbouring samples $p[x, y]$ that are constructed luma samples prior to the deblocking filter process, with $x = -1, y = -1..15$ and with $x = 0..15, y = -1$, are derived as follows.

- The derivation process for neighbouring locations in subclause 6.4.9 is invoked for luma locations with (x, y) assigned to (xN, yN) as input and mbAddrN and (xW, yW) as output.
- Each sample $p[x, y]$ with $x = -1, y = -1..15$ and with $x = 0..15, y = -1$ is derived as follows.
 - If any of the following conditions is true, the sample $p[x, y]$ is marked as “not available for Intra_16x16 prediction”
 - mbAddrN is not available,
 - the macroblock mbAddrN is coded in Inter prediction mode and $\text{constrained_intra_pred_flag}$ is equal to 1.

- the macroblock mbAddrN has mb_type equal to SI and constrained_intra_pred_flag is equal to 1.
- Otherwise, the sample p[x, y] is marked as “available for Intra_16x16 prediction” and the luma sample at luma location (xW, yW) inside the macroblock mbAddrN is assigned to p[x, y].

Let pred_L[x, y] with x, y = 0..15 denote the prediction samples for the 16x16 luma block samples.

Intra_16x16 prediction modes are specified in Table 8-4.

Table 8-4 – Specification of Intra16x16PredMode and associated names

Intra16x16PredMode	Name of Intra16x16PredMode
0	Intra_16x16_Vertical (prediction mode)
1	Intra_16x16_Horizontal (prediction mode)
2	Intra_16x16_DC (prediction mode)
3	Intra_16x16_Plane (prediction mode)

Depending on Intra16x16PredMode, one of the Intra_16x16 prediction modes specified in subclauses 8.3.3.1 to 8.3.3.4 is invoked.

8.3.3.1 Specification of Intra_16x16_Vertical prediction mode

This Intra_16x16 prediction mode shall be used only when the samples p[x, -1] with x = 0..15 are marked as “available for Intra_16x16 prediction”.

$$\text{pred}_L[x, y] = p[x, -1], \text{ with } x, y = 0..15 \quad (8-112)$$

8.3.3.2 Specification of Intra_16x16_Horizontal prediction mode

This Intra_16x16 prediction mode shall be used only when the samples p[-1, y] with y = 0..15 are marked as “available for Intra_16x16 prediction”.

$$\text{pred}_L[x, y] = p[-1, y], \text{ with } x, y = 0..15 \quad (8-113)$$

8.3.3.3 Specification of Intra_16x16_DC prediction mode

This Intra_16x16 prediction mode operates, depending on whether the neighbouring samples are marked as “available for Intra_16x16 prediction”, as follows.

- If all neighbouring samples p[x, -1], with x = 0..15 and p[-1, y], with y = 0..15 are marked as “available for Intra_16x16 prediction”, the prediction for all luma samples in the macroblock is given by:

$$\text{pred}_L[x, y] = \left(\sum_{x'=0}^{15} p[x', -1] + \sum_{y'=0}^{15} p[-1, y'] + 16 \right) \gg 5, \text{ with } x, y = 0..15 \quad (8-114)$$

- Otherwise, if any of the neighbouring samples p[x, -1], with x = 0..15 are marked as "not available for Intra_16x16 prediction" and all of the neighbouring samples p[-1, y], with y = 0..15 are marked as “available for Intra_16x16 prediction”, the prediction for all luma samples in the macroblock is given by:

$$\text{pred}_L[x, y] = \left(\sum_{y'=0}^{15} p[-1, y'] + 8 \right) \gg 4, \text{ with } x, y = 0..15 \quad (8-115)$$

- Otherwise, if any of the neighbouring samples p[-1, y], with y = 0..15 are marked as "not available for Intra_16x16 prediction" and all of the neighbouring samples p[x, -1], with x = 0..15 are marked as “available for Intra_16x16 prediction”, the prediction for all luma samples in the macroblock is given by:

$$\text{pred}_L[x, y] = \left(\sum_{x'=0}^{15} p[x', -1] + 8 \right) \gg 4, \text{ with } x, y = 0..15 \quad (8-116)$$

- Otherwise (some of the neighbouring samples $p[x, -1]$, with $x = 0..15$ and some of the neighbouring samples $p[-1, y]$, with $y = 0..15$ are marked as “not available for Intra_16x16 prediction”), the prediction for all luma samples in the macroblock is given by:

$$\text{pred}_L[x, y] = (1 \ll (\text{BitDepth}_Y - 1)), \text{ with } x, y = 0..15 \quad (8-117)$$

8.3.3.4 Specification of Intra_16x16 Plane prediction mode

This Intra_16x16 prediction mode shall be used only when the samples $p[x, -1]$ with $x = -1..15$ and $p[-1, y]$ with $y = 0..15$ are marked as “available for Intra_16x16 prediction”.

$$\text{pred}_L[x, y] = \text{Clip}_{1Y}((a + b * (x - 7) + c * (y - 7) + 16) \gg 5), \text{ with } x, y = 0..15, \quad (8-118)$$

where:

$$a = 16 * (p[-1, 15] + p[15, -1]) \quad (8-119)$$

$$b = (5 * H + 32) \gg 6 \quad (8-120)$$

$$c = (5 * V + 32) \gg 6 \quad (8-121)$$

and H and V are specified in Equations 8-122 and 8-123.

$$H = \sum_{x'=0}^7 (x'+1) * (p[8+x', -1] - p[6-x', -1]) \quad (8-122)$$

$$V = \sum_{y'=0}^7 (y'+1) * (p[-1, 8+y'] - p[-1, 6-y']) \quad (8-123)$$

8.3.4 Intra prediction process for chroma samples

This process is invoked for I and SI macroblock types. It specifies how the Intra prediction chroma samples for the current macroblock are derived.

Outputs of this process are Intra prediction chroma samples for the current macroblock $\text{pred}_{Cb}[x, y]$ and $\text{pred}_{Cr}[x, y]$.

Both chroma blocks (Cb and Cr) of the macroblock use the same prediction mode. The prediction mode is applied to each of the chroma blocks separately. The process specified in this subclause is invoked for each chroma block. In the remainder of this subclause, chroma block refers to one of the two chroma blocks and the subscript C is used as a replacement of the subscript Cb or Cr.

The neighbouring samples $p[x, y]$ that are constructed chroma samples prior to the deblocking filter process, with $x = -1, y = -1..MbHeightC - 1$ and with $x = 0..MbWidthC - 1, y = -1$, are derived as follows.

- The derivation process for neighbouring locations in subclause 6.4.9 is invoked for chroma locations with (x, y) assigned to (xN, yN) as input and $mbAddrN$ and (xW, yW) as output.
- Each sample $p[x, y]$ is derived as follows.
 - If any of the following conditions is true, the sample $p[x, y]$ is marked as “not available for Intra chroma prediction”
 - $mbAddrN$ is not available,
 - the macroblock $mbAddrN$ is coded in Inter prediction mode and $\text{constrained_intra_pred_flag}$ is equal to 1.
 - the macroblock $mbAddrN$ has mb_type equal to SI and $\text{constrained_intra_pred_flag}$ is equal to 1 and the current macroblock does not have mb_type equal to SI.
 - Otherwise, the sample $p[x, y]$ is marked as “available for Intra chroma prediction” and the chroma sample of component C at chroma location (xW, yW) inside the macroblock $mbAddrN$ is assigned to $p[x, y]$.

Let $\text{pred}_c[x, y]$ with $x = 0..MbWidthC - 1$, $y = 0..MbHeightC - 1$ denote the prediction samples for the chroma block samples.

Intra chroma prediction modes are specified in Table 8-5.

Table 8-5 – Specification of Intra chroma prediction modes and associated names

intra_chroma_pred_mode	Name of intra_chroma_pred_mode
0	Intra_Chroma_DC (prediction mode)
1	Intra_Chroma_Horizontal (prediction mode)
2	Intra_Chroma_Vertical (prediction mode)
3	Intra_Chroma_Plane (prediction mode)

Depending on `intra_chroma_pred_mode`, one of the Intra chroma prediction modes specified in subclauses 8.3.4.1 to 8.3.4.4 is invoked.

8.3.4.1 Specification of Intra_Chroma_DC prediction mode

This Intra chroma prediction mode is invoked when `intra_chroma_pred_mode` is equal to 0.

For each chroma block of 4x4 samples indexed by $\text{chroma4x4BlkIdx} = 0..(1 \ll (\text{chroma_format_idc} + 1)) - 1$, the following applies.

- Depending on `chroma_format_idc`, the position of the upper-left sample of a 4x4 chroma block with index `chroma4x4BlkIdx` is derived as follows

- If `chroma_format_idc` is equal to 1 or 2, the following applies

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 0) \quad (8-124)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 1) \quad (8-125)$$

- Otherwise (`chroma_format_idc` is equal to 3), the following applies

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 0) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 0) \quad (8-126)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 1) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 1) \quad (8-127)$$

- If (xO, yO) is equal to $(0, 0)$ or xO and yO are greater than 0, the values of the prediction samples $\text{pred}_c[x + xO, y + yO]$ with $x, y = 0..3$ are derived as follows.

- If all samples $p[x + xO, -1]$, with $x = 0..3$ and $p[-1, y + yO]$, with $y = 0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_c[x + xO, y + yO]$, with $x, y = 0..3$ are derived as

$$\text{pred}_c[x + xO, y + yO] = \left(\sum_{x'=0}^3 p[x'+xO, -1] + \sum_{y'=0}^3 p[-1, y'+yO] + 4 \right) \gg 3, \text{ with } x, y = 0..3. \quad (8-128)$$

- Otherwise, if any samples $p[x + xO, -1]$, with $x = 0..3$ are marked as “not available for Intra chroma prediction” and all samples $p[-1, y + yO]$, with $y = 0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_c[x + xO, y + yO]$, with $x, y = 0..3$ are derived as

$$\text{pred}_c[x + xO, y + yO] = \left(\sum_{y'=0}^3 p[-1, y'+yO] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-129)$$

- Otherwise, if any samples $p[-1, y+yO]$, with $y=0..3$ are marked as “not available for Intra chroma prediction” and all samples $p[x+xO, -1]$, with $x=0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = \left(\sum_{x'=0}^3 p[x'+xO, -1] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-130)$$

- Otherwise (some samples $p[x+xO, -1]$, with $x=0..3$ and some samples $p[-1, y+yO]$, with $y=0..3$ are marked as “not available for Intra chroma prediction”), the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = (1 \ll (\text{BitDepth}_C - 1)), \text{ with } x, y = 0..3. \quad (8-131)$$

- Otherwise, if xO is greater than 0 and yO is equal to 0, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$ with $x, y=0..3$ are derived as follows.

- If all samples $p[x+xO, -1]$, with $x=0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = \left(\sum_{x'=0}^3 p[x'+xO, -1] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-132)$$

- Otherwise, if all samples $p[-1, y+yO]$, with $y=0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = \left(\sum_{y'=0}^3 p[-1, y'+yO] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-133)$$

- Otherwise (some samples $p[x+xO, -1]$, with $x=0..3$ and some samples $p[-1, y+yO]$, with $y=0..3$ are marked as “not available for Intra chroma prediction”), the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = (1 \ll (\text{BitDepth}_C - 1)), \text{ with } x, y = 0..3. \quad (8-134)$$

- Otherwise (xO is equal to 0 and yO is greater than 0), the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$ with $x, y=0..3$ are derived as follows.

- If all samples $p[-1, y+yO]$, with $y=0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = \left(\sum_{y'=0}^3 p[-1, y'+yO] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-135)$$

- Otherwise, if all samples $p[x+xO, -1]$, with $x=0..3$ are marked as “available for Intra chroma prediction”, the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = \left(\sum_{x'=0}^3 p[x'+xO, -1] + 2 \right) \gg 2, \text{ with } x, y = 0..3. \quad (8-136)$$

- Otherwise (some samples $p[x+xO, -1]$, with $x=0..3$ and some samples $p[-1, y+yO]$, with $y=0..3$ are marked as “not available for Intra chroma prediction”), the values of the prediction samples $\text{pred}_C[x+xO, y+yO]$, with $x, y=0..3$ are derived as

$$\text{pred}_C[x+xO, y+yO] = (1 \ll (\text{BitDepth}_C - 1)), \text{ with } x, y = 0..3. \quad (8-137)$$

8.3.4.2 Specification of Intra_Chroma_Horizontal prediction mode

This Intra chroma prediction mode is invoked when `intra_chroma_pred_mode` is equal to 1.

This mode shall be used only when the samples $p[-1, y]$ with $y = 0..MbHeightC - 1$ are marked as "available for Intra chroma prediction".

The values of the prediction samples $pred_c[x, y]$ are derived as follows.

$$pred_c[x, y] = p[-1, y], \text{ with } x = 0..MbWidthC - 1 \text{ and } y = 0..MbHeightC - 1 \quad (8-138)$$

8.3.4.3 Specification of Intra_Chroma_Vertical prediction mode

This Intra chroma prediction mode is invoked when `intra_chroma_pred_mode` is equal to 2.

This mode shall be used only when the samples $p[x, -1]$ with $x = 0..MbWidthC - 1$ are marked as "available for Intra chroma prediction".

The values of the prediction samples $pred_c[x, y]$ are derived as follows.

$$pred_c[x, y] = p[x, -1], \text{ with } x = 0..MbWidthC - 1 \text{ and } y = 0..MbHeightC - 1 \quad (8-139)$$

8.3.4.4 Specification of Intra_Chroma_Plane prediction mode

This Intra chroma prediction mode is invoked when `intra_chroma_pred_mode` is equal to 3.

This mode shall be used only when the samples $p[x, -1]$, with $x = 0..MbWidthC - 1$ and $p[-1, y]$, with $y = -1..MbHeightC - 1$ are marked as "available for Intra chroma prediction".

The values of the prediction samples $pred_c[x, y]$ are derived as follows.

Let the variable `xCF` be set equal to $4 * (\text{chroma_format_idc} == 3)$ and let the variable `yCF` be set equal to $4 * (\text{chroma_format_idc} != 1)$.

$$pred_c[x, y] = \text{Clip1}_c((a + b * (x - 3 - xCF) + c * (y - 3 - yCF) + 16) \gg 5), \text{ with } x = 0..MbWidthC - 1 \text{ and } y = 0..MbHeightC - 1 \quad (8-140)$$

where:

$$a = 16 * (p[-1, MbHeightC - 1] + p[MbWidthC - 1, -1]) \quad (8-141)$$

$$b = ((34 - 29 * (\text{chroma_format_idc} == 3)) * H + 32) \gg 6 \quad (8-142)$$

$$c = ((34 - 29 * (\text{chroma_format_idc} != 1)) * V + 32) \gg 6 \quad (8-143)$$

and `H` and `V` are specified as

$$H = \sum_{x'=0}^{3+xCF} (x'+1) * (p[4+xCF+x', -1] - p[2+xCF-x', -1]) \quad (8-144)$$

$$V = \sum_{y'=0}^{3+yCF} (y'+1) * (p[-1, 4+yCF+y'] - p[-1, 2+yCF-y']) \quad (8-145)$$

8.3.5 Sample construction process for I_PCM macroblocks

This process is invoked when `mb_type` is equal to `I_PCM`.

The variable `dy` is derived as follows.

- If `MbaffFrameFlag` is equal to 1 and the current macroblock is a field macroblock, `dy` is set equal to 2.
- Otherwise (`MbaffFrameFlag` is equal to 0 or the current macroblock is a frame macroblock), `dy` is set equal to 1.

The position of the upper-left luma sample of the current macroblock is derived by invoking the inverse macroblock scanning process in subclause 6.4.1 with CurrMbAddr as input and the output being assigned to (xP, yP).

The constructed luma samples prior to the deblocking process are generated as specified by:

$$\text{for}(i = 0; i < 256; i++) \\ S'_L[xP + (i \% 16), yP + dy * (i / 16)] = \text{pcm_sample_luma}[i] \quad (8-146)$$

When chroma_format_idc is not equal to 0 (monochrome), the constructed chroma samples prior to the deblocking process are generated as specified by:

$$\text{for}(i = 0; i < \text{MbWidthC} * \text{MbHeightC}; i++) \{ \\ S'_{Cb}[(xP / \text{SubWidthC}) + (i \% \text{MbWidthC}), \\ \quad ((yP + \text{SubHeightC} - 1) / \text{SubHeightC}) + dy * (i / \text{MbWidthC})] = \\ \quad \text{pcm_sample_chroma}[i] \\ S'_{Cr}[(xP / \text{SubWidthC}) + (i \% \text{MbWidthC}), \\ \quad ((yP + \text{SubHeightC} - 1) / \text{SubHeightC}) + dy * (i / \text{MbWidthC})] = \\ \quad \text{pcm_sample_chroma}[i + \text{MbWidthC} * \text{MbHeightC}] \\ \} \quad (8-147)$$

8.4 Inter prediction process

This process is invoked when decoding P and B macroblock types.

Outputs of this process are Inter prediction samples for the current macroblock that are a 16x16 array pred_L of luma samples and when chroma_format_idc is not equal to 0 (monochrome) two 8x8 arrays pred_{Cr} and pred_{Cb} of chroma samples, one for each of the chroma components Cb and Cr.

The partitioning of a macroblock is specified by mb_type. Each macroblock partition is referred to by mbPartIdx. When the macroblock partitioning consists of partitions that are equal to sub-macroblocks, each sub-macroblock can be further partitioned into sub-macroblock partitions as specified by sub_mb_type. Each sub-macroblock partition is referred to by subMbPartIdx. When the macroblock partitioning does not consist of sub-macroblocks, subMbPartIdx is set equal to 0.

The following steps are specified for each macroblock partition or for each sub-macroblock partition.

The functions MbPartWidth(), MbPartHeight(), SubMbPartWidth(), and SubMbPartHeight() describing the width and height of macroblock partitions and sub-macroblock partitions are specified in Tables 7-13, 7-14, 7-17, and 7-18.

The range of the macroblock partition index mbPartIdx is derived as follows.

- If mb_type is equal to B_Skip or B_Direct_16x16, mbPartIdx proceeds over values 0..3.
- Otherwise (mb_type is not equal to B_Skip or B_Direct_16x16), mbPartIdx proceeds over values 0..NumMbPart(mb_type) – 1.

For each value of mbPartIdx, the variables partWidth and partHeight for each macroblock partition or sub-macroblock partition in the macroblock are derived as follows.

- If mb_type is not equal to P_8x8, P_8x8ref0, B_Skip, B_Direct_16x16, or B_8x8, subMbPartIdx is set equal to 0, and partWidth and partHeight are derived as

$$\text{partWidth} = \text{MbPartWidth}(\text{mb_type}) \quad (8-148)$$

$$\text{partHeight} = \text{MbPartHeight}(\text{mb_type}) \quad (8-149)$$

- Otherwise, if mb_type is equal to P_8x8 or P_8x8ref0, or mb_type is equal to B_8x8 and sub_mb_type[mbPartIdx] is not equal to B_Direct_8x8, subMbPartIdx proceeds over values 0..NumSubMbPart(sub_mb_type) – 1, and partWidth and partHeight are derived as

$$\text{partWidth} = \text{SubMbPartWidth}(\text{sub_mb_type}[\text{mbPartIdx}]) \quad (8-150)$$

$$\text{partHeight} = \text{SubMbPartHeight}(\text{sub_mb_type}[\text{mbPartIdx}]). \quad (8-151)$$

- Otherwise (`mb_type` is equal to `B_Skip` or `B_Direct_16x16`, or `mb_type` is equal to `B_8x8` and `sub_mb_type[mbPartIdx]` is equal to `B_Direct_8x8`), `subMbPartIdx` proceeds over values 0..3, and `partWidth` and `partHeight` are derived as

$$\text{partWidth} = 4 \quad (8-152)$$

$$\text{partHeight} = 4 \quad (8-153)$$

When `chroma_format_idc` is not equal to 0 (monochrome) the variables `partWidthC` and `partHeightC` are derived as

$$\text{partWidthC} = \text{partWidth} / \text{SubWidthC} \quad (8-154)$$

$$\text{partHeightC} = \text{partHeight} / \text{SubHeightC} \quad (8-155)$$

Let the variable `MvCnt` be initially set equal to 0 before any invocation of subclause 8.4.1 for the macroblock.

The Inter prediction process for a macroblock partition `mbPartIdx` and a sub-macroblock partition `subMbPartIdx` consists of the following ordered steps

1. Derivation process for motion vector components and reference indices as specified in subclause 8.4.1.

Inputs to this process are

- a macroblock partition `mbPartIdx`,
- a sub-macroblock partition `subMbPartIdx`.

Outputs of this process are

- luma motion vectors `mvL0` and `mvL1` and when `chroma_format_idc` is not equal to 0 (monochrome) the chroma motion vectors `mvCL0` and `mvCL1`
- reference indices `refIdxL0` and `refIdxL1`
- prediction list utilization flags `predFlagL0` and `predFlagL1`
- the sub-macroblock partition motion vector count `subMvCnt`.

2. The variable `MvCnt` is incremented by `subMvCnt`.

3. Decoding process for Inter prediction samples as specified in subclause 8.4.2.

Inputs to this process are

- a macroblock partition `mbPartIdx`,
- a sub-macroblock partition `subMbPartIdx`.
- variables specifying partition width and height for luma and chroma (if available), `partWidth`, `partHeight`, `partWidthC` (if available), and `partHeightC` (if available)
- luma motion vectors `mvL0` and `mvL1` and when `chroma_format_idc` is not equal to 0 (monochrome) the chroma motion vectors `mvCL0` and `mvCL1`
- reference indices `refIdxL0` and `refIdxL1`
- prediction list utilization flags `predFlagL0` and `predFlagL1`

Outputs of this process are

- inter prediction samples (`pred`); which are a $(\text{partWidth}) \times (\text{partHeight})$ array `predPartL` of prediction luma samples and when `chroma_format_idc` is not equal to 0 (monochrome) two $(\text{partWidthC}) \times (\text{partHeightC})$ arrays `predPartCr`, and `predPartCb` of prediction chroma samples, one for each of the chroma components `Cb` and `Cr`.

For use in derivation processes of variables invoked later in the decoding process, the following assignments are made:

$$\text{MvL0}[\text{mbPartIdx}][\text{subMbPartIdx}] = \text{mvL0} \quad (8-156)$$

$$\text{MvL1}[\text{mbPartIdx}][\text{subMbPartIdx}] = \text{mvL1} \quad (8-157)$$

$$\text{RefIdxL0}[\text{mbPartIdx}] = \text{refIdxL0} \quad (8-158)$$

$$\text{RefIdxL1}[\text{mbPartIdx}] = \text{refIdxL1} \quad (8-159)$$

$$\text{PredFlagL0}[\text{mbPartIdx}] = \text{predFlagL0} \quad (8-160)$$

$$\text{PredFlagL1}[\text{mbPartIdx}] = \text{predFlagL1} \quad (8-161)$$

The location of the upper-left sample of the partition relative to the upper-left sample of the macroblock is derived by invoking the inverse macroblock partition scanning process as described in subclause 6.4.2.1 with `mbPartIdx` as the input and `(xP, yP)` as the output.

The location of the upper-left sample of the macroblock sub-partition relative to the upper-left sample of the macroblock partition is derived by invoking the inverse sub-macroblock partition scanning process as described in subclause 6.4.2.2 with `subMbPartIdx` as the input and `(xS, yS)` as the output.

The macroblock prediction is formed by placing the partition or sub-macroblock partition prediction samples in their correct relative positions in the macroblock, as follows.

The variable `predL[xP + xS + x, yP + yS + y]` with `x = 0 .. partWidth - 1, y = 0 .. partHeight - 1` is derived by

$$\text{predL}[\text{xP} + \text{xS} + \text{x}, \text{yP} + \text{yS} + \text{y}] = \text{predPartL}[\text{x}, \text{y}] \quad (8-162)$$

When `chroma_format_idc` is not equal to 0 (monochrome) the variable `predC` with `x = 0..partWidthC - 1, y = 0..partHeightC - 1`, and C in `predC` and `predPartC` being replaced by Cb or Cr is derived by

$$\text{predC}[\text{xP} / \text{SubWidthC} + \text{xS} / \text{SubWidthC} + \text{x}, \text{yP} / \text{SubHeightC} + \text{yS} / \text{SubHeightC} + \text{y}] = \text{predPartC}[\text{x}, \text{y}] \quad (8-163)$$

8.4.1 Derivation process for motion vector components and reference indices

Inputs to this process are

- a macroblock partition `mbPartIdx`,
- a sub-macroblock partition `subMbPartIdx`.

Outputs of this process are

- luma motion vectors `mvL0` and `mvL1` as well as the chroma motion vectors `mvCL0` and `mvCL1`
- reference indices `refIdxL0` and `refIdxL1`
- prediction list utilization flags `predFlagL0` and `predFlagL1`
- a sub-partition macroblock motion vector count variable `subMvCnt`

For the derivation of the variables `mvL0` and `mvL1` as well as `refIdxL0` and `refIdxL1`, the following applies.

- If `mb_type` is equal to `P_Skip`, the derivation process for luma motion vectors for skipped macroblocks in P and SP slices in subclause 8.4.1.1 is invoked with the output being the luma motion vectors `mvL0` and reference indices `refIdxL0`, and `predFlagL0` is set equal to 1. `mvL1` and `refIdxL1` are marked as not available and `predFlagL1` is set equal to 0. The sub-partition motion vector count variable `subMvCnt` is set equal to 1.
- Otherwise, if `mb_type` is equal to `B_Skip` or `B_Direct_16x16` or `sub_mb_type[mbPartIdx]` is equal to `B_Direct_8x8`, the derivation process for luma motion vectors for `B_Skip`, `B_Direct_16x16`, and `B_Direct_8x8` in B slices in subclause 8.4.1.2 is invoked with `mbPartIdx` and `subMbPartIdx` as the input and the output being the luma motion vectors `mvL0`, `mvL1`, the reference indices `refIdxL0`, `refIdxL1`, the sub-partition motion vector count `subMvCnt`, and the prediction utilization flags `predFlagL0` and `predFlagL1`.
- Otherwise, for X being replaced by either 0 or 1 in the variables `predFlagLX`, `mvLX`, `refIdxLX`, and in `Pred_LX` and in the syntax elements `ref_idx_IX` and `mvd_IX`, the following applies.

1. The variables $refIdxLX$ and $predFlagLX$ are derived as follows.

- If $MbPartPredMode(mb_type, mbPartIdx)$ or $SubMbPredMode(sub_mb_type[mbPartIdx])$ is equal to $Pred_LX$ or to $BiPred$,

$$refIdxLX = ref_idx_lX[mbPartIdx] \quad (8-164)$$

$$predFlagLX = 1 \quad (8-165)$$

- Otherwise, the variables $refIdxLX$ and $predFlagLX$ are specified by

$$refIdxLX = -1 \quad (8-166)$$

$$predFlagLX = 0 \quad (8-167)$$

2. The variable $subMvCnt$ for sub-partition motion vector count is set equal to $predFlagL0 + predFlagL1$.

3. The variable $currSubMbType$ is derived as follows.

- If the macroblock type is equal to B_8x8 , $currSubMbType$ is set equal to $sub_mb_type[mbPartIdx]$.
- Otherwise (the macroblock type is not equal to B_8x8), $currSubMbType$ is set equal to "na".

4. When $predFlagLX$ is equal to 1, the derivation process for luma motion vector prediction in subclause 8.4.1.3 is invoked with $mbPartIdx$, $subMbPartIdx$, $refIdxLX$, and $currSubMbType$ as the inputs and the output being $mvLX$. The luma motion vectors are derived by

$$mvLX[0] = mvpLX[0] + mvd_lX[mbPartIdx][subMbPartIdx][0] \quad (8-168)$$

$$mvLX[1] = mvpLX[1] + mvd_lX[mbPartIdx][subMbPartIdx][1] \quad (8-169)$$

For the derivation of the variables for the chroma motion vectors, the following applies. When $predFlagLX$ (with X being either 0 or 1) is equal to 1, the derivation process for chroma motion vectors in subclause 8.4.1.4 is invoked with $mvLX$ and $refIdxLX$ as input and the output being $mvCLX$.

8.4.1.1 Derivation process for luma motion vectors for skipped macroblocks in P and SP slices

This process is invoked when mb_type is equal to P_Skip .

Outputs of this process are the motion vector $mvL0$ and the reference index $refIdxL0$.

The reference index $refIdxL0$ for a skipped macroblock is derived as follows.

$$refIdxL0 = 0. \quad (8-170)$$

For the derivation of the motion vector $mvL0$ of a P_Skip macroblock type, the following applies.

- The process specified in subclause 8.4.1.3.2 is invoked with $mbPartIdx$ set equal to 0, $subMbPartIdx$ set equal to 0, $currSubMbType$ set equal to "na", and $listSuffixFlag$ set equal to 0 as input and the output is assigned to $mbAddrA$, $mbAddrB$, $mvL0A$, $mvL0B$, $refIdxL0A$, and $refIdxL0B$.
- The variable $mvL0$ is specified as follows.
 - If any of the following conditions are true, both components of the motion vector $mvL0$ are set equal to 0.
 - $mbAddrA$ is not available
 - $mbAddrB$ is not available
 - $refIdxL0A$ is equal to 0 and both components of $mvL0A$ are equal to 0
 - $refIdxL0B$ is equal to 0 and both components of $mvL0B$ are equal to 0

- Otherwise, the derivation process for luma motion vector prediction as specified in subclause 8.4.1.3 is invoked with `mbPartIdx = 0`, `subMbPartIdx = 0`, `refIdxL0`, and `currSubMbType = "na"` as inputs and the output is assigned to `mvL0`.

NOTE – The output is directly assigned to `mvL0`, since the predictor is equal to the actual motion vector.

8.4.1.2 Derivation process for luma motion vectors for B_Skip, B_Direct_16x16, and B_Direct_8x8

This process is invoked when `mb_type` is equal to `B_Skip` or `B_Direct_16x16`, or `sub_mb_type[mbPartIdx]` is equal to `B_Direct_8x8`.

Inputs to this process are `mbPartIdx` and `subMbPartIdx`.

Outputs of this process are the reference indices `refIdxL0`, `refIdxL1`, the motion vectors `mvL0` and `mvL1`, the sub-partition motion vector count `subMvCnt`, and the prediction list utilization flags, `predFlagL0` and `predFlagL1`.

The derivation process depends on the value of `direct_spatial_mv_pred_flag`, which is present in the bitstream in the slice header syntax as specified in subclause 7.3.3, and is specified as follows.

- If `direct_spatial_mv_pred_flag` is equal to 1, the mode in which the outputs of this process are derived is referred to as spatial direct prediction mode.
- Otherwise (`direct_spatial_mv_pred_flag` is equal to 0), mode in which the outputs of this process are derived is referred to as temporal direct prediction mode.

Both spatial and temporal direct prediction mode use the co-located motion vectors and reference indices as specified in subclause 8.4.1.2.1.

The motion vectors and reference indices are derived as follows.

- If spatial direct prediction mode is used, the direct motion vector and reference index prediction mode specified in subclause 8.4.1.2.2 is used, with `subMvCnt` being an output.
- Otherwise (temporal direct prediction mode is used), the direct motion vector and reference index prediction mode specified in subclause 8.4.1.2.3 is used and the variable `subMvCnt` is derived as follows.
 - If `subMbPartIdx` is equal to 0, `subMvCnt` is set equal to 2.
 - Otherwise (`subMbPartIdx` is not equal to 0), `subMvCnt` is set equal to 0.

8.4.1.2.1 Derivation process for the co-located 4x4 sub-macroblock partitions

Inputs to this process are `mbPartIdx` and `subMbPartIdx`.

Outputs of this process are the picture `colPic`, the co-located macroblock `mbAddrCol`, the motion vector `mvCol`, the reference index `refIdxCol`, and the variable `vertMvScale` (which can be `One_To_One`, `Frm_To_Fld` or `Fld_To_Frm`).

When `RefPicList1[0]` is a frame or a complementary field pair, let `firstRefPicL1Top` and `firstRefPicL1Bottom` be the top and bottom fields of `RefPicList1[0]`, respectively, and let the following variables be specified as

$$\text{topAbsDiffPOC} = \text{Abs}(\text{DiffPicOrderCnt}(\text{firstRefPicL1Top}, \text{CurrPic})) \quad (8-171)$$

$$\text{bottomAbsDiffPOC} = \text{Abs}(\text{DiffPicOrderCnt}(\text{firstRefPicL1Bottom}, \text{CurrPic})) \quad (8-172)$$

The variable colPic specifies the picture that contains the co-located macroblock as specified in Table 8-6.

Table 8-6 – Specification of the variable colPic

field_pic_flag	RefPicList1[0] is ...	mb_field_decoding_flag	additional condition	colPic
1	a field of a decoded frame			the frame containing RefPicList1[0]
	a decoded field			RefPicList1[0]
0	a decoded frame			RefPicList1[0]
	a complementary field pair	0	topAbsDiffPOC < bottomAbsDiffPOC	firstRefPicL1Top
			topAbsDiffPOC >= bottomAbsDiffPOC	firstRefPicL1Bottom
		1	(CurrMbAddr & 1) == 0	firstRefPicL1Top
(CurrMbAddr & 1) != 0			firstRefPicL1Bottom	

When direct_8x8_inference_flag is equal to 1, subMbPartIdx is set as follows.

$$\text{subMbPartIdx} = \text{mbPartIdx} \quad (8-173)$$

Let PicCodingStruct(X) be a function with the argument X being either CurrPic or colPic. It is specified in Table 8-7.

Table 8-7 – Specification of PicCodingStruct(X)

X is coded with field_pic_flag equal to ...	mb_adaptive_frame_field_flag	PicCodingStruct(X)
1		FLD
0	0	FRM
0	1	AFRM

With luma4x4BlkIdx = mbPartIdx * 4 + subMbPartIdx, the inverse 4x4 luma block scanning process as specified in subclause 6.4.3 is invoked with luma4x4BlkIdx as the input and (x, y) assigned to (xCol, yCol) as the output.

Table 8-8 specifies the co-located macroblock address mbAddrCol, yM, and the variable vertMvScale in two steps:

1. Specification of a macroblock address mbAddrX depending on PicCodingStruct(CurrPic), and PicCodingStruct(colPic).

NOTE – It is not possible for CurrPic and colPic picture coding types to be either (FRM, AFRM) or (AFRM, FRM) because these picture coding types must be separated by an IDR picture.

2. Specification of mbAddrCol, yM, and vertMvScale depending on mb_field_decoding_flag and the variable fieldDecodingFlagX, which is derived as follows.
 - If the macroblock mbAddrX in the picture colPic is a field macroblock, fieldDecodingFlagX is set equal to 1
 - Otherwise (the macroblock mbAddrX in the picture colPic is a frame macroblock), fieldDecodingFlagX is set equal to 0.

Unspecified values in Table 8-8 indicate that the value of the corresponding variable is not relevant for the current table row.

mbAddrCol is set equal to CurrMbAddr or to one of the following values.

$$\text{mbAddrCol1} = 2 * \text{PicWidthInMbs} * (\text{CurrMbAddr} / \text{PicWidthInMbs}) + (\text{CurrMbAddr} \% \text{PicWidthInMbs}) + \text{PicWidthInMbs} * (\text{yCol} / 8) \quad (8-174)$$

$$\text{mbAddrCol2} = 2 * \text{CurrMbAddr} + (\text{yCol} / 8) \quad (8-175)$$

$$\text{mbAddrCol3} = 2 * \text{CurrMbAddr} + \text{bottom_field_flag} \quad (8-176)$$

$$\text{mbAddrCol4} = \text{PicWidthInMbs} * (\text{CurrMbAddr} / (2 * \text{PicWidthInMbs})) + (\text{CurrMbAddr} \% \text{PicWidthInMbs}) \quad (8-177)$$

$$\text{mbAddrCol5} = \text{CurrMbAddr} / 2 \quad (8-178)$$

$$\text{mbAddrCol6} = 2 * (\text{CurrMbAddr} / 2) + ((\text{topAbsDiffPOC} < \text{bottomAbsDiffPOC}) ? 0 : 1) \quad (8-179)$$

$$\text{mbAddrCol7} = 2 * (\text{CurrMbAddr} / 2) + (\text{yCol} / 8) \quad (8-180)$$

Table 8-8 – Specification of mbAddrCol, yM, and vertMvScale

PicCodingStruct(CurrPic)	PicCodingStruct(colPic)	mbAddrX	mb_field_decoding_flag	fieldDecodingFlagX	mbAddrCol	yM	vertMvScale
FLD	FLD				CurrMbAddr	yCol	One_To_One
	FRM				mbAddrCol1	(2 * yCol) % 16	Frm_To_Fld
	AFRM	2*CurrMbAddr	0		mbAddrCol2	(2 * yCol) % 16	Frm_To_Fld
1				mbAddrCol3	yCol	One_To_One	
FRM	FLD				mbAddrCol4	8 * ((CurrMbAddr / PicWidthInMbs) % 2) + 4 * (yCol / 8)	Fld_To_Frm
	FRM				CurrMbAddr	yCol	One_To_One
AFRM	FLD		0		mbAddrCol5	8 * (CurrMbAddr % 2) + 4 * (yCol / 8)	Fld_To_Frm
			1		mbAddrCol5	yCol	One_To_One
	AFRM	CurrMbAddr	0		CurrMbAddr	yCol	One_To_One
			1		mbAddrCol6	8 * (CurrMbAddr % 2) + 4 * (yCol / 8)	Fld_To_Frm
	AFRM	CurrMbAddr	0		mbAddrCol7	(2 * yCol) % 16	Frm_To_Fld
			1		CurrMbAddr	yCol	One_To_One

Let mbPartIdxCol be the macroblock partition index of the co-located partition and subMbPartIdxCol the sub-macroblock partition index of the co-located sub-macroblock partition. The partition in the macroblock mbAddrCol inside the picture colPic covering the sample (xCol, yM) is assigned to mbPartIdxCol and the sub-macroblock partition inside the partition mbPartIdxCol covering the sample (xCol, yM) in the macroblock mbAddrCol inside the picture colPic is assigned to subMbPartIdxCol.

The prediction utilization flags `predFlagL0Col` and `predFlagL1Col` are set equal to `PredFlagL0[mbPartIdxCol]` and `PredFlagL1[mbPartIdxCol]`, respectively, which are the prediction utilization flags that have been assigned to the macroblock partition `mbAddrCol\mbPartIdxCol` inside the picture `colPic`.

The motion vector `mvCol` and the reference index `refIdxCol` are derived as follows.

- If the macroblock `mbAddrCol` is coded in Intra macroblock prediction mode or both prediction utilization flags, `predFlagL0Col` and `predFlagL1Col` are equal to 0, both components of `mvCol` are set equal to 0 and `refIdxCol` is set equal to -1.
- Otherwise, the following applies.
 - If `predFlagL0Col` is equal to 1, the motion vector `mvCol` and the reference index `refIdxCol` are set equal to `MvL0[mbPartIdxCol][subMbPartIdxCol]` and `RefIdxL0[mbPartIdxCol]`, respectively, which are the motion vector `mvL0` and the reference index `refIdxL0` that have been assigned to the (sub-)macroblock partition `mbAddrCol\mbPartIdxCol\subMbPartIdxCol` inside the picture `colPic`.
 - Otherwise (`predFlagL0Col` is equal to 0 and `predFlagL1Col` is equal to 1), the motion vector `mvCol` and the reference index `refIdxCol` are set equal to `MvL1[mbPartIdxCol][subMbPartIdxCol]` and `RefIdxL1[mbPartIdxCol]`, respectively, which are the motion vector `mvL1` and the reference index `refIdxL1` that have been assigned to the (sub-)macroblock partition `mbAddrCol\mbPartIdxCol\subMbPartIdxCol` inside the picture `colPic`.

8.4.1.2.2 Derivation process for spatial direct luma motion vector and reference index prediction mode

This process is invoked when `direct_spatial_mv_pred_flag` is equal to 1 and any of the following conditions is true.

- `mb_type` is equal to `B_Skip`
- `mb_type` is equal to `B_Direct_16x16`
- `sub_mb_type[mbPartIdx]` is equal to `B_Direct_8x8`.

Inputs to this process are `mbPartIdx`, `subMbPartIdx`.

Outputs of this process are the reference indices `refIdxL0`, `refIdxL1`, the motion vectors `mvL0` and `mvL1`, the sub-partition motion vector count `subMvCnt`, and the prediction list utilization flags, `predFlagL0` and `predFlagL1`.

The reference indices `refIdxL0` and `refIdxL1` and the variable `directZeroPredictionFlag` are derived by applying the following ordered steps.

1. Let the variable `currSubMbType` be set equal to `sub_mb_type[mbPartIdx]`.
2. The process specified in subclause 8.4.1.3.2 is invoked with `mbPartIdx = 0`, `subMbPartIdx = 0`, `currSubMbType`, and `listSuffixFlag = 0` as inputs and the output is assigned to the motion vectors `mvL0N` and the reference indices `refIdxL0N` with `N` being replaced by `A`, `B`, or `C`.
3. The process specified in subclause 8.4.1.3.2 is invoked with `mbPartIdx = 0`, `subMbPartIdx = 0`, `currSubMbType`, and `listSuffixFlag = 1` as inputs and the output is assigned to the motion vectors `mvL1N` and the reference indices `refIdxL1N` with `N` being replaced by `A`, `B`, or `C`.

NOTE 1 – The motion vectors `mvL0N`, `mvL1N` and the reference indices `refIdxL0N`, `refIdxL1N` are identical for all 4x4 sub-macroblock partitions of a macroblock.

4. The reference indices `refIdxL0`, `refIdxL1`, and `directZeroPredictionFlag` are derived by

$$\text{refIdxL0} = \text{MinPositive}(\text{refIdxL0A}, \text{MinPositive}(\text{refIdxL0B}, \text{refIdxL0C})) \quad (8-181)$$

$$\text{refIdxL1} = \text{MinPositive}(\text{refIdxL1A}, \text{MinPositive}(\text{refIdxL1B}, \text{refIdxL1C})) \quad (8-182)$$

$$\text{directZeroPredictionFlag} = 0 \quad (8-183)$$

where

$$\text{MinPositive}(x, y) = \begin{cases} \text{Min}(x, y) & \text{if } x \geq 0 \text{ and } y \geq 0 \\ \text{Max}(x, y) & \text{otherwise} \end{cases} \quad (8-184)$$

5. When both reference indices $refIdxL0$ and $refIdxL1$ are less than 0,

$$refIdxL0 = 0 \quad (8-185)$$

$$refIdxL1 = 0 \quad (8-186)$$

$$directZeroPredictionFlag = 1 \quad (8-187)$$

The process specified in subclause 8.4.1.2.1 is invoked with $mbPartIdx$, $subMbPartIdx$ given as input and the output is assigned to $refIdxCol$ and $mvCol$.

The variable $colZeroFlag$ is derived as follows.

- If all of the following conditions are true, $colZeroFlag$ is set equal to 1.
 - $RefPicList1[0]$ is currently marked as "used for short-term reference".
 - $refIdxCol$ is equal to 0
 - both motion vector components $mvCol[0]$ and $mvCol[1]$ lie in the range of -1 to 1 in units specified as follows.
 - If the co-located macroblock is a frame macroblock, the units of $mvCol[0]$ and $mvCol[1]$ are units of quarter luma frame samples.
 - Otherwise (the co-located macroblock is a field macroblock), the units of $mvCol[0]$ and $mvCol[1]$ are units of quarter luma field samples.

NOTE 2 – For purposes of determining the condition above, the value $mvCol[1]$ is not scaled to use the units of a motion vector for the current macroblock in cases when the current macroblock is a frame macroblock and the co-located macroblock is a field macroblock or when the current macroblock is a field macroblock and the co-located macroblock is a frame macroblock. This aspect differs from the use of $mvCol[1]$ in the temporal direct mode as specified in subclause 8.4.1.2.3, which applies scaling to the motion vector of the co-located macroblock to use the same units as the units of a motion vector for the current macroblock, using Equation 8-190 or Equation 8-191 in these cases.

- Otherwise, $colZeroFlag$ is set equal to 0.

The motion vectors $mvLX$ (with X being 0 or 1) are derived as follows.

- If any of the following conditions is true, both components of the motion vector $mvLX$ are set equal to 0.
 - $directZeroPredictionFlag$ is equal to 1
 - $refIdxLX$ is less than 0
 - $refIdxLX$ is equal to 0 and $colZeroFlag$ is equal to 1
- Otherwise, the process specified in subclause 8.4.1.3 is invoked with $mbPartIdx = 0$, $subMbPartIdx = 0$, $refIdxLX$, and $currSubMbType$ as inputs and the output is assigned to $mvLX$.

NOTE 3 – The motion vector $mvLX$ returned from subclause 8.4.1.3 is identical for all 4x4 sub-macroblock partitions of a macroblock for which the process is invoked.

The prediction utilization flags $predFlagL0$ and $predFlagL1$ are derived as specified using Table 8-9.

Table 8-9 – Assignment of prediction utilization flags

$refIdxL0$	$refIdxL1$	$predFlagL0$	$predFlagL1$
≥ 0	≥ 0	1	1
≥ 0	< 0	1	0
< 0	≥ 0	0	1

The variable $subMvCnt$ is derived as follows.

- If $subMbPartIdx$ is not equal to 0 or $direct_8x8_inference_flag$ is equal to 0, $subMvCnt$ is set equal to 0.
- Otherwise ($subMbPartIdx$ is equal to 0 and $direct_8x8_inference_flag$ is equal to 1), $subMvCnt$ is set equal to $predFlagL0 + predFlagL1$.

8.4.1.2.3 Derivation process for temporal direct luma motion vector and reference index prediction mode

This process is invoked when `direct_spatial_mv_pred_flag` is equal to 0 and any of the following conditions is true.

- `mb_type` is equal to `B_Skip`
- `mb_type` is equal to `B_Direct_16x16`
- `sub_mb_type[mbPartIdx]` is equal to `B_Direct_8x8`.

Inputs to this process are `mbPartIdx` and `subMbPartIdx`.

Outputs of this process are the motion vectors `mvL0` and `mvL1`, the reference indices `refIdxL0` and `refIdxL1`, and the prediction list utilization flags, `predFlagL0` and `predFlagL1`.

The process specified in subclause 8.4.1.2.1 is invoked with `mbPartIdx`, `subMbPartIdx` given as input and the output is assigned to `colPic`, `mbAddrCol`, `mvCol`, `refIdxCol`, and `vertMvScale`.

The reference indices `refIdxL0` and `refIdxL1` are derived as follows.

$$\text{refIdxL0} = ((\text{refIdxCol} < 0) ? 0 : \text{MapColToList0}(\text{refIdxCol})) \quad (8-188)$$

$$\text{refIdxL1} = 0 \quad (8-189)$$

NOTE 1 – If the current macroblock is a field macroblock, `refIdxL0` and `refIdxL1` index a list of fields; otherwise (the current macroblock is a frame macroblock), `refIdxL0` and `refIdxL1` index a list of frames or complementary reference field pairs.

Let `refPicCol` be a frame, a field, or a complementary field pair that was referred by the reference index `refIdxCol` when decoding the co-located macroblock `mbAddrCol` inside the picture `colPic`. The function `MapColToList0(refIdxCol)` is specified as follows.

- If `vertMvScale` is equal to `One_To_One`, the following applies.
 - If `field_pic_flag` is equal to 0 and the current macroblock is a field macroblock, the following applies.
 - Let `refIdxL0Frm` be the lowest valued reference index in the current reference picture list `RefPicList0` that references the frame or complementary field pair that contains the field `refPicCol`. `RefPicList0` shall contain a frame or complementary field pair that contains the field `refPicCol`. The return value of `MapColToList0()` is specified as follows.
 - If the field referred to by `refIdxCol` has the same parity as the current macroblock, `MapColToList0(refIdxCol)` returns the reference index $(\text{refIdxL0Frm} \ll 1)$.
 - Otherwise (the field referred by `refIdxCol` has the opposite parity of the current macroblock), `MapColToList0(refIdxCol)` returns the reference index $((\text{refIdxL0Frm} \ll 1) + 1)$.
 - Otherwise (`field_pic_flag` is equal to 1 or the current macroblock is a frame macroblock), `MapColToList0(refIdxCol)` returns the lowest valued reference index `refIdxL0` in the current reference picture list `RefPicList0` that references `refPicCol`. `RefPicList0` shall contain `refPicCol`.
 - Otherwise, if `vertMvScale` is equal to `Frm_To_Fld`, the following applies.
 - If `field_pic_flag` is equal to 0, let `refIdxL0Frm` be the lowest valued reference index in the current reference picture list `RefPicList0` that references `refPicCol`. `MapColToList0(refIdxCol)` returns the reference index $(\text{refIdxL0Frm} \ll 1)$. `RefPicList0` shall contain `refPicCol`.
 - Otherwise (`field_pic_flag` is equal to 1), `MapColToList0(refIdxCol)` returns the lowest valued reference index `refIdxL0` in the current reference picture list `RefPicList0` that references the field of `refPicCol` with the same parity as the current picture `CurrPic`. `RefPicList0` shall contain the field of `refPicCol` with the same parity as the current picture `CurrPic`.
 - Otherwise (`vertMvScale` is equal to `Fld_To_Frm`), `MapColToList0(refIdxCol)` returns the lowest valued reference index `refIdxL0` in the current reference picture list `RefPicList0` that references the frame or complementary field pair that contains `refPicCol`. `RefPicList0` shall contain a frame or complementary field pair that contains the field `refPicCol`.

NOTE 2 – A decoded reference picture that was marked as "used for short-term reference" when it was referenced in the decoding process of the picture containing the co-located macroblock may have been modified to be marked as "used for long-term reference" before being used for reference for inter prediction using the direct prediction mode for the current macroblock.

Depending on the value of `vertMvScale` the vertical component of `mvCol` is modified as follows.

- If `vertMvScale` is equal to `Frm_To_Fld`

$$\text{mvCol}[1] = \text{mvCol}[1] / 2 \quad (8-190)$$

- Otherwise, if `vertMvScale` is equal to `Fld_To_Frm`

$$\text{mvCol}[1] = \text{mvCol}[1] * 2 \quad (8-191)$$

- Otherwise (`vertMvScale` is equal to `One_To_One`), `mvCol[1]` remains unchanged.

The variables `currPicOrField`, `pic0`, and `pic1`, are derived as follows.

- If `field_pic_flag` is equal to 0 and the current macroblock is a field macroblock, the following applies.

- `currPicOrField` is the field of the current picture `CurrPic` that has the same parity as the current macroblock.

- `pic1` is the field of `RefPicList1[0]` that has the same parity as the current macroblock.

- The variable `pic0` is derived as follows.

- If `refIdxL0 % 2` is equal to 0, `pic0` is the field of `RefPicList0[refIdxL0 / 2]` that has the same parity as the current macroblock.

- Otherwise (`refIdxL0 % 2` is not equal to 0), `pic0` is the field of `RefPicList0[refIdxL0 / 2]` that has the opposite parity of the current macroblock.

- Otherwise (`field_pic_flag` is equal to 1 or the current macroblock is a frame macroblock), `currPicOrField` is the current picture `CurrPic`, `pic1` is the decoded reference picture `RefPicList1[0]`, and `pic0` is the decoded reference picture `RefPicList0[refIdxL0]`.

The two motion vectors `mvL0` and `mvL1` for each 4x4 sub-macroblock partition of the current macroblock are derived as follows:

NOTE 3 – It is often the case that many of the 4x4 sub-macroblock partitions share the same motion vectors and reference pictures. In these cases, temporal direct mode motion compensation can calculate the inter prediction sample values in larger units than 4x4 luma sample blocks. For example, when `direct_8x8_inference_flag` is equal to 1, at least each 8x8 luma sample quadrant of the macroblock shares the same motion vectors and reference pictures.

- If the reference index `refIdxL0` refers to a long-term reference picture, or `DiffPicOrderCnt(pic1, pic0)` is equal to 0, the motion vectors `mvL0`, `mvL1` for the direct mode partition are derived by

$$\text{mvL0} = \text{mvCol} \quad (8-192)$$

$$\text{mvL1} = 0 \quad (8-193)$$

- Otherwise, the motion vectors `mvL0`, `mvL1` are derived as scaled versions of the motion vector `mvCol` of the co-located sub-macroblock partition as specified below (see Figure 8-2)

$$\text{tx} = (16384 + \text{Abs}(\text{td} / 2)) / \text{td} \quad (8-194)$$

$$\text{DistScaleFactor} = \text{Clip3}(-1024, 1023, (\text{tb} * \text{tx} + 32) \gg 6) \quad (8-195)$$

$$\text{mvL0} = (\text{DistScaleFactor} * \text{mvCol} + 128) \gg 8 \quad (8-196)$$

$$\text{mvL1} = \text{mvL0} - \text{mvCol} \quad (8-197)$$

where `tb` and `td` are derived as follows.

$$\text{tb} = \text{Clip3}(-128, 127, \text{DiffPicOrderCnt}(\text{currPicOrField}, \text{pic0})) \quad (8-198)$$

$$\text{td} = \text{Clip3}(-128, 127, \text{DiffPicOrderCnt}(\text{pic1}, \text{pic0})) \quad (8-199)$$

NOTE 4 – mvL0 and mvL1 cannot exceed the ranges specified in Annex A.

The prediction utilization flags predFlagL0 and predFlagL1 are both set equal to 1.

Figure 8-2 illustrates the temporal direct-mode motion vector inference when the current picture is temporally between the reference picture from reference picture list 0 and the reference picture from reference picture list 1.

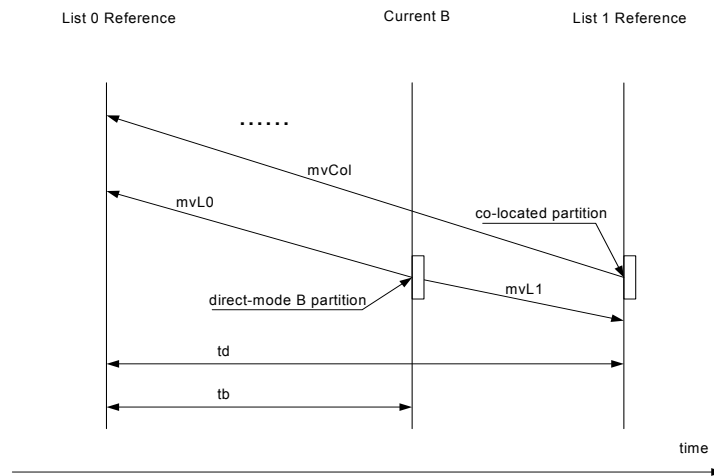


Figure 8-2 – Example for temporal direct-mode motion vector inference (informative)

8.4.1.3 Derivation process for luma motion vector prediction

Inputs to this process are

- the macroblock partition index mbPartIdx,
- the sub-macroblock partition index subMbPartIdx,
- the reference index of the current partition refIdxLX (with X being 0 or 1),
- the variable currSubMbType.

Output of this process is the prediction mvpLX of the motion vector mvLX (with X being 0 or 1).

The derivation process for the neighbouring blocks for motion data in subclause 8.4.1.3.2 is invoked with mbPartIdx, subMbPartIdx, currSubMbType, and listSuffixFlag = X (with X being 0 or 1 for refIdxLX being refIdxL0 or refIdxL1, respectively) as the input and with mbAddrN\mbPartIdxN\subMbPartIdxN, reference indices refIdxLXN and the motion vectors mvLXN with N being replaced by A, B, or C as the output.

The derivation process for median luma motion vector prediction in subclause 8.4.1.3.1 is invoked with mbAddrN\mbPartIdxN\subMbPartIdxN, mvLXN, refIdxLXN with N being replaced by A, B, or C and refIdxLX as the input and mvpLX as the output, unless one of the following is true.

- MbPartWidth(mb_type) is equal to 16, MbPartHeight(mb_type) is equal to 8, mbPartIdx is equal to 0, and refIdxLXB is equal to refIdxLX,

$$\text{mvpLX} = \text{mvLXB} \quad (8-200)$$

- MbPartWidth(mb_type) is equal to 16, MbPartHeight(mb_type) is equal to 8, mbPartIdx is equal to 1, and refIdxLXA is equal to refIdxLX,

$$\text{mvpLX} = \text{mvLXA} \quad (8-201)$$

- MbPartWidth(mb_type) is equal to 8, MbPartHeight(mb_type) is equal to 16, mbPartIdx is equal to 0, and refIdxLXA is equal to refIdxLX,

$$\text{mvpLX} = \text{mvLXA} \quad (8-202)$$

- MbPartWidth(mb_type) is equal to 8, MbPartHeight(mb_type) is equal to 16, mbPartIdx is equal to 1, and refIdxLXC is equal to refIdxLX,

$$mvpLX = mvLXC \quad (8-203)$$

Figure 8-3 illustrates the non-median prediction as described above.

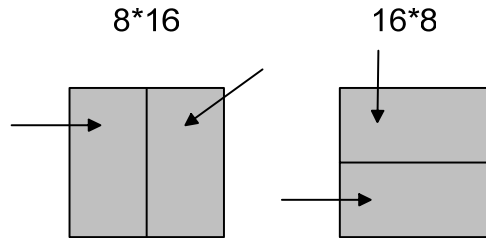


Figure 8-3 – Directional segmentation prediction (informative)

8.4.1.3.1 Derivation process for median luma motion vector prediction

Inputs to this process are

- the neighbouring partitions mbAddrN\mbPartIdxN\subMbPartIdxN (with N being replaced by A, B, or C),
- the motion vectors mvLXN (with N being replaced by A, B, or C) of the neighbouring partitions,
- the reference indices refIdxLXN (with N being replaced by A, B, or C) of the neighbouring partitions, and
- the reference index refIdxLX of the current partition.

Output of this process is the motion vector prediction mvpLX.

The variable mvpLX is derived as follows:

- When both partitions mbAddrB\mbPartIdxB\subMbPartIdxB and mbAddrC\mbPartIdxC\subMbPartIdxC are not available and mbAddrA\mbPartIdxA\subMbPartIdxA is available,

$$mvLXB = mvLXA \quad (8-204)$$

$$mvLXC = mvLXA \quad (8-205)$$

$$refIdxLXB = refIdxLXA \quad (8-206)$$

$$refIdxLXC = refIdxLXA \quad (8-207)$$

- Depending on reference indices refIdxLXA, refIdxLXB, or refIdxLXC, the following applies.
 - If one and only one of the reference indices refIdxLXA, refIdxLXB, or refIdxLXC is equal to the reference index refIdxLX of the current partition, the following applies. Let refIdxLXN be the reference index that is equal to refIdxLX, the motion vector mvLXN is assigned to the motion vector prediction mvpLX:

$$mvpLX = mvLXN \quad (8-208)$$

- Otherwise, each component of the motion vector prediction mvpLX is given by the median of the corresponding vector components of the motion vector mvLXA, mvLXB, and mvLXC:

$$mvpLX[0] = \text{Median}(mvLXA[0], mvLXB[0], mvLXC[0]) \quad (8-209)$$

$$\text{mvLX}[1] = \text{Median}(\text{mvLXA}[1], \text{mvLXB}[1], \text{mvLXC}[1]) \quad (8-210)$$

8.4.1.3.2 Derivation process for motion data of neighbouring partitions

Inputs to this process are

- the macroblock partition index mbPartIdx ,
- the sub-macroblock partition index subMbPartIdx ,
- the current sub-macroblock type currSubMbType ,
- the list suffix flag listSuffixFlag

Outputs of this process are (with N being replaced by A, B, or C)

- $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$ specifying neighbouring partitions,
- the motion vectors mvLXN of the neighbouring partitions, and
- the reference indices refIdxLXN of the neighbouring partitions.

Variable names that include the string "LX" are interpreted with the X being equal to listSuffixFlag .

The partitions $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$ with N being either A, B, or C are derived in the following ordered steps.

1. Let $\text{mbAddrD}\backslash\text{mbPartIdxD}\backslash\text{subMbPartIdxD}$ be variables specifying an additional neighbouring partition.
2. The process in subclause 6.4.8.5 is invoked with mbPartIdx , currSubMbType , and subMbPartIdx as input and the output is assigned to $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$ with N being replaced by A, B, C, or D.
3. When the partition $\text{mbAddrC}\backslash\text{mbPartIdxC}\backslash\text{subMbPartIdxC}$ is not available, the following applies

$$\text{mbAddrC} = \text{mbAddrD} \quad (8-211)$$

$$\text{mbPartIdxC} = \text{mbPartIdxD} \quad (8-212)$$

$$\text{subMbPartIdxC} = \text{subMbPartIdxD} \quad (8-213)$$

The motion vectors mvLXN and reference indices refIdxLXN (with N being A, B, or C) are derived as follows.

- If the macroblock partition or sub-macroblock partition $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$ is not available or mbAddrN is coded in Intra prediction mode or predFlagLX of $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$ is equal to 0, both components of mvLXN are set equal to 0 and refIdxLXN is set equal to -1.
- Otherwise, the following applies.
 - The motion vector mvLXN and reference index refIdxLXN are set equal to $\text{MvLX}[\text{mbPartIdxN}][\text{subMbPartIdxN}]$ and $\text{RefIdxLX}[\text{mbPartIdxN}]$, respectively, which are the motion vector mvLX and reference index refIdxLX that have been assigned to the (sub-)macroblock partition $\text{mbAddrN}\backslash\text{mbPartIdxN}\backslash\text{subMbPartIdxN}$.
 - The variables $\text{mvLXN}[1]$ and refIdxLXN are further processed as follows.

- If the current macroblock is a field macroblock and the macroblock mbAddrN is a frame macroblock

$$\text{mvLXN}[1] = \text{mvLXN}[1] / 2 \quad (8-214)$$

$$\text{refIdxLXN} = \text{refIdxLXN} * 2 \quad (8-215)$$

- Otherwise, if the current macroblock is a frame macroblock and the macroblock mbAddrN is a field macroblock

$$\text{mvLXN}[1] = \text{mvLXN}[1] * 2 \quad (8-216)$$

$$\text{refIdxLXN} = \text{refIdxLXN} / 2 \quad (8-217)$$

- Otherwise, the vertical motion vector component $\text{mvLXN}[1]$ and the reference index refIdxLXN remain unchanged.

8.4.1.4 Derivation process for chroma motion vectors

This process is only invoked when chroma_format_idc is not equal to 0 (monochrome).

Inputs to this process are a luma motion vector mvLX and a reference index refIdxLX .

Output of this process is a chroma motion vector mvCLX .

A chroma motion vector is derived from the corresponding luma motion vector.

The precision of the chroma motion vector components is $1 \div (4 * \text{SubWidthC})$ horizontally and $1 \div (4 * \text{SubHeightC})$ vertically.

NOTE – For example, when using the 4:2:0 chroma format, since the units of luma motion vectors are one-quarter luma sample units and chroma has half horizontal and vertical resolution compared to luma, the units of chroma motion vectors are one-eighth chroma sample units, i.e., a value of 1 for the chroma motion vector refers to a one-eighth chroma sample displacement. For example, when the luma vector applies to 8x16 luma samples, the corresponding chroma vector in 4:2:0 chroma format applies to 4x8 chroma samples and when the luma vector applies to 4x4 luma samples, the corresponding chroma vector in 4:2:0 chroma format applies to 2x2 chroma samples.

For the derivation of the motion vector mvCLX , the following applies.

- If chroma_format_idc is not equal to 1 or the current macroblock is a frame macroblock, the horizontal and vertical components of the chroma motion vector mvCLX are derived as

$$\text{mvCLX}[0] = \text{mvLX}[0] \quad (8-218)$$

$$\text{mvCLX}[1] = \text{mvLX}[1] \quad (8-219)$$

- Otherwise (chroma_format_idc is equal to 1 and the current macroblock is a field macroblock), only the horizontal component of the chroma motion vector $\text{mvCLX}[0]$ is derived using Equation 8-218. The vertical component of the chroma motion vector $\text{mvCLX}[1]$ is dependent on the parity of the current field or the current macroblock and the reference picture, which is referred by the reference index refIdxLX . $\text{mvCLX}[1]$ is derived from $\text{mvLX}[1]$ according to Table 8-10.

Table 8-10 – Derivation of the vertical component of the chroma vector in field coding mode

Parity conditions		$\text{mvCLX}[1]$
Reference picture (refIdxLX)	Current field (picture/macroblock)	
Top field	Bottom field	$\text{mvLX}[1] + 2$
Bottom field	Top field	$\text{mvLX}[1] - 2$
Otherwise		$\text{mvLX}[1]$

8.4.2 Decoding process for Inter prediction samples

Inputs to this process are

- a macroblock partition mbPartIdx ,
- a sub-macroblock partition subMbPartIdx .
- variables specifying partition width and height for luma and chroma (if available), partWidth , partHeight , partWidthC (if available) and partHeightC (if available)
- luma motion vectors mvL0 and mvL1 and when chroma_format_idc is not equal to 0 (monochrome) chroma motion vectors mvCL0 and mvCL1
- reference indices refIdxL0 and refIdxL1

- prediction list utilization flags, predFlagL0 and predFlagL1

Outputs of this process are

- the Inter prediction samples predPart, which are a (partWidth)x(partHeight) array predPart_L of prediction luma samples, and when chroma_format_idc is not equal to 0 (monochrome) two (partWidthC)x(partHeightC) arrays predPart_{Cb}, predPart_{Cr} of prediction chroma samples, one for each of the chroma components Cb and Cr.

Let predPartL0_L and predPartL1_L be (partWidth)x(partHeight) arrays of predicted luma sample values and when chroma_format_idc is not equal to 0 (monochrome) predPartL0_{Cb}, predPartL1_{Cb}, predPartL0_{Cr}, and predPartL1_{Cr} be (partWidthC)x(partHeightC) arrays of predicted chroma sample values.

For LX being replaced by either L0 or L1 in the variables predFlagLX, RefPicListX, refIdxLX, refPicLX, predPartLX, the following is specified.

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 when chroma_format_idc is not equal to 0 (monochrome) two ordered two-dimensional arrays refPicLX_{Cb} and refPicLX_{Cr} of chroma samples is derived by invoking the process specified in subclause 8.4.2.1 with refIdxLX and RefPicListX given as input.
- The array predPartLX_L and when chroma_format_idc is not equal to 0 (monochrome) the arrays predPartLX_{Cb} and predPartLX_{Cr} are derived by invoking the process specified in subclause 8.4.2.2 with the current partition specified by mbPartIdx\subMbPartIdx, the motion vectors mvLX, mvCLX (if available), and the reference arrays with refPicLX_L, refPicLX_{Cb} (if available), and refPicLX_{Cr} (if available) given as input.

For C being replaced by L, Cb (if available), or Cr (if available), the array predPart_C of the prediction samples of component C is derived by invoking the process specified in subclause 8.4.2.3 with the current partition specified by mbPartIdx and subMbPartIdx and the array predPartL0_C and predPartL1_C as well as predFlagL0 and predFlagL1 given as input.

8.4.2.1 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}.

Depending on field_pic_flag, the reference picture list RefPicListX (which has been derived as specified in subclause 8.2.4) consists of the following.

- If field_pic_flag is equal to 1, each entry of RefPicListX is a reference field or a field of a reference frame.
- Otherwise (field_pic_flag is equal to 0), each entry of RefPicListX is a reference frame or a complementary reference field pair.

For the derivation of the reference picture, the following applies.

- If field_pic_flag is equal to 1, the reference field or field of a reference frame RefPicListX[refIdxLX] is the output. The output reference field or field of a reference frame consists of a (PicWidthInSamples_L)x(PicHeightInSamples_L) array of luma samples refPicLX_L and, when chroma_format_idc is not equal to 0 (monochrome), two (PicWidthInSamples_C)x(PicHeightInSamples_C) arrays of chroma samples refPicLX_{Cb} and refPicLX_{Cr}.
- Otherwise (field_pic_flag is equal to 0), the following applies.
 - If the current macroblock is a frame macroblock, the reference frame or complementary reference field pair RefPicListX[refIdxLX] is the output. The output reference frame or complementary reference field pair consists of a (PicWidthInSamples_L)x(PicHeightInSamples_L) array of luma samples refPicLX_L and, when chroma_format_idc is not equal to 0 (monochrome), two (PicWidthInSamples_C)x(PicHeightInSamples_C) arrays of chroma samples refPicLX_{Cb} and refPicLX_{Cr}.
 - Otherwise (the current macroblock is a field macroblock), the following applies.
 - Let refFrame be the reference frame or complementary reference field pair RefPicListX[refIdxLX / 2].
 - The field of refFrame is selected as follows.
 - If refIdxLX % 2 is equal to 0, the field of refFrame that has the same parity as the current macroblock is the output.

- Otherwise ($\text{refIdxLX} \% 2$ is equal to 1), the field of refFrame that has the opposite parity as the current macroblock is the output.
- The output reference field or field of a reference frame consists of a $(\text{PicWidthInSamples}_L) \times (\text{PicHeightInSamples}_L / 2)$ array of luma samples refPicLX_L and, when chroma_format_idc is not equal to 0 (monochrome), two $(\text{PicWidthInSamples}_C) \times (\text{PicHeightInSamples}_C / 2)$ arrays of chroma samples refPicLX_{Cb} and refPicLX_{Cr} .

The reference picture sample arrays refPicLX_L , refPicLX_{Cb} (if available), and refPicLX_{Cr} (if available) correspond to decoded sample arrays S_L , S_{Cb} (if available), S_{Cr} (if available) derived in subclause 8.7 for a previously-decoded reference field or reference frame or complementary reference field pair or field of a reference frame.

8.4.2.2 Fractional sample interpolation process

Inputs to this process are

- the current partition given by its partition index mbPartIdx and its sub-macroblock partition index subMbPartIdx ,
- the width and height partWidth , partHeight of this partition in luma-sample units,
- a luma motion vector mvLX given in quarter-luma-sample units,
- a chroma motion vector mvCLX given in eighth-chroma-sample units, and
- the selected reference picture sample arrays refPicLX_L , refPicLX_{Cb} , and refPicLX_{Cr}

Outputs of this process are

- a $(\text{partWidth}) \times (\text{partHeight})$ array predPartLX_L of prediction luma sample values and
- when chroma_format_idc is not equal to 0 (monochrome) two $(\text{partWidthC}) \times (\text{partHeightC})$ arrays predPartLX_{Cb} , and predPartLX_{Cr} of prediction chroma sample values.

Let (x_{A_L}, y_{A_L}) be the location given in full-sample units of the upper-left luma sample of the current partition given by $\text{mbPartIdx} \setminus \text{subMbPartIdx}$ relative to the upper-left luma sample location of the given two-dimensional array of luma samples.

Let $(x_{\text{Int}_L}, y_{\text{Int}_L})$ be a luma location given in full-sample units and $(x_{\text{Frac}_L}, y_{\text{Frac}_L})$ be an offset given in quarter-sample units. These variables are used only inside this subclause for specifying general fractional-sample locations inside the reference sample arrays refPicLX_L , refPicLX_{Cb} (if available), and refPicLX_{Cr} (if available).

For each luma sample location ($0 \leq x_L < \text{partWidth}$, $0 \leq y_L < \text{partHeight}$) inside the prediction luma sample array predPartLX_L , the corresponding prediction luma sample value $\text{predPartLX}_L[x_L, y_L]$ is derived as follows:

- The variables x_{Int_L} , y_{Int_L} , x_{Frac_L} , and y_{Frac_L} are derived by

$$x_{\text{Int}_L} = x_{A_L} + (\text{mvLX}[0] \gg 2) + x_L \quad (8-220)$$

$$y_{\text{Int}_L} = y_{A_L} + (\text{mvLX}[1] \gg 2) + y_L \quad (8-221)$$

$$x_{\text{Frac}_L} = \text{mvLX}[0] \& 3 \quad (8-222)$$

$$y_{\text{Frac}_L} = \text{mvLX}[1] \& 3 \quad (8-223)$$

- The prediction luma sample value $\text{predPartLX}_L[x_L, y_L]$ is derived by invoking the process specified in subclause 8.4.2.2.1 with $(x_{\text{Int}_L}, y_{\text{Int}_L})$, $(x_{\text{Frac}_L}, y_{\text{Frac}_L})$ and refPicLX_L given as input.

When chroma_format_idc is not equal to 0 (monochrome), the following applies.

Let $(x_{\text{Int}_C}, y_{\text{Int}_C})$ be a chroma location given in full-sample units and $(x_{\text{Frac}_C}, y_{\text{Frac}_C})$ 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 ($0 \leq x_C < \text{partWidthC}$, $0 \leq y_C < \text{partHeightC}$) inside the prediction chroma sample arrays predPartLX_{Cb} and predPartLX_{Cr} , the corresponding prediction chroma sample values $\text{predPartLX}_{Cb}[x_C, y_C]$ and $\text{predPartLX}_{Cr}[x_C, y_C]$ are derived as follows:

- Depending on chroma_format_idc , the variables x_{Int_C} , y_{Int_C} , x_{Frac_C} , and y_{Frac_C} are derived as follows.
 - If chroma_format_idc is equal to 1,

$$xInt_C = (xA_L / SubWidthC) + (mvCLX[0] \gg 3) + x_C \quad (8-224)$$

$$yInt_C = (yA_L / SubHeightC) + (mvCLX[1] \gg 3) + y_C \quad (8-225)$$

$$xFrac_C = mvCLX[0] \& 7 \quad (8-226)$$

$$yFrac_C = mvCLX[1] \& 7 \quad (8-227)$$

- Otherwise, if chroma_format_idc is equal to 2,

$$xInt_C = (xA_L / SubWidthC) + (mvCLX[0] \gg 3) + x_C \quad (8-228)$$

$$yInt_C = (yA_L / SubHeightC) + (mvCLX[1] \gg 2) + y_C \quad (8-229)$$

$$xFrac_C = mvCLX[0] \& 7 \quad (8-230)$$

$$yFrac_C = (mvCLX[1] \& 3) \ll 1 \quad (8-231)$$

- Otherwise (chroma_format_idc is equal to 3),

$$xInt_C = (xA_L / SubWidthC) + (mvCLX[0] \gg 2) + x_C \quad (8-232)$$

$$yInt_C = (yA_L / SubHeightC) + (mvCLX[1] \gg 2) + y_C \quad (8-233)$$

$$xFrac_C = (mvCLX[0] \& 3) \ll 1 \quad (8-234)$$

$$yFrac_C = (mvCLX[1] \& 3) \ll 1 \quad (8-235)$$

- The prediction sample value $predPartLX_{Cb}[x_C, y_C]$ is derived by invoking the process specified in subclause 8.4.2.2.2 with $(xInt_C, yInt_C)$, $(xFrac_C, yFrac_C)$ and $refPicLX_{Cb}$ given as input.
- The prediction sample value $predPartLX_{Cr}[x_C, y_C]$ is derived by invoking the process specified in subclause 8.4.2.2.2 with $(xInt_C, yInt_C)$, $(xFrac_C, yFrac_C)$ and $refPicLX_{Cr}$ given as input.

8.4.2.2.1 Luma sample interpolation process

Inputs to this process are

- a luma location in full-sample units $(xInt_L, yInt_L)$,
- a luma location offset in fractional-sample units $(xFrac_L, yFrac_L)$, and
- the luma sample array of the selected reference picture $refPicLX_L$

Output of this process is a predicted luma sample value $predPartLX_L[x_L, y_L]$.

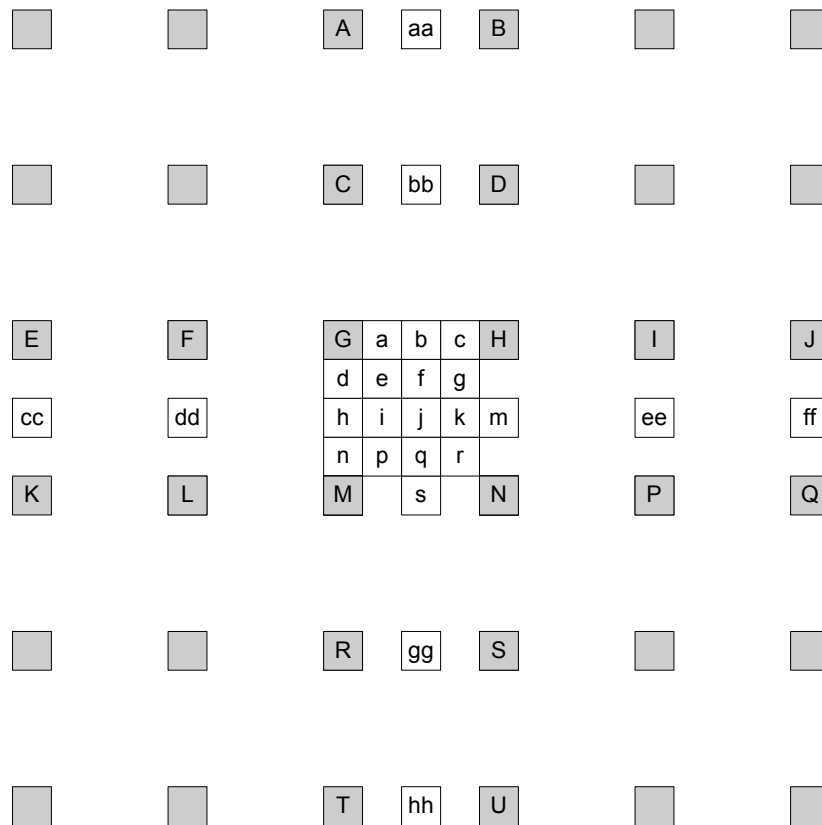


Figure 8-4 – Integer samples (shaded blocks with upper-case letters) and fractional sample positions (un-shaded blocks with lower-case letters) for quarter sample luma interpolation

The variable $refPicHeightEffective_L$, which is the height of the effective reference picture luma array, is derived as follows.

- If $MbaffFrameFlag$ is equal to 0 or $mb_field_decoding_flag$ is equal to 0, $refPicHeightEffective_L$ is set equal to $PicHeightInSamples_L$.
- Otherwise ($MbaffFrameFlag$ is equal to 1 and $mb_field_decoding_flag$ is equal to 1), $refPicHeightEffective_L$ is set equal to $PicHeightInSamples_L / 2$.

In Figure 8-4, the positions labelled with upper-case letters 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 $predPartLX_L[x_L, y_L]$. The locations (xZ_L, yZ_L) for each of the corresponding luma samples Z , where Z may be A, B, C, D, E, F, G, H, I, J, K, L, M, N, P, Q, R, S, T, or U, inside the given array $refPicLX_L$ of luma samples are derived as follows:

$$\begin{aligned} xZ_L &= \text{Clip3}(0, PicWidthInSamples_L - 1, xInt_L + xDZ_L) \\ yZ_L &= \text{Clip3}(0, refPicHeightEffective_L - 1, yInt_L + yDZ_L) \end{aligned} \quad (8-236)$$

Table 8-11 specifies (xDZ_L, yDZ_L) for different replacements of Z .

Table 8-11 – Differential full-sample luma locations

Z	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	Q	R	S	T	U
xDZ_L	0	1	0	1	-2	-1	0	1	2	3	-2	-1	0	1	2	3	0	1	0	1
yDZ_L	-2	-2	-1	-1	0	0	0	0	0	0	1	1	1	1	1	1	2	2	3	3

Given the luma samples ‘A’ to ‘U’ at full-sample locations (x_{A_L}, y_{A_L}) to (x_{U_L}, y_{U_L}), the luma samples ‘a’ to ‘s’ at fractional sample positions are derived by the following rules. The luma prediction values at half sample positions are derived by applying a 6-tap filter with tap values (1, -5, 20, 20, -5, 1). The luma prediction values at quarter sample positions are derived by averaging samples at full and half sample positions. The process for each fractional position is described below.

- The samples at half sample positions labelled b are derived by first calculating intermediate values denoted as b_1 by applying the 6-tap filter to the nearest integer position samples in the horizontal direction. The samples at half sample positions labelled h are derived by first calculating intermediate values denoted as h_1 by applying the 6-tap filter to the nearest integer position samples in the vertical direction:

$$b_1 = (E - 5 * F + 20 * G + 20 * H - 5 * I + J) \quad (8-237)$$

$$h_1 = (A - 5 * C + 20 * G + 20 * M - 5 * R + T) \quad (8-238)$$

The final prediction values b and h are derived using:

$$b = \text{Clip1}_Y((b_1 + 16) \ggg 5) \quad (8-239)$$

$$h = \text{Clip1}_Y((h_1 + 16) \ggg 5) \quad (8-240)$$

- The samples at half sample position labelled as j are derived by first calculating intermediate value denoted as j_1 by applying the 6-tap filter to the intermediate values of the closest half sample positions in either the horizontal or vertical direction because these yield an equal result.

$$j_1 = cc - 5 * dd + 20 * h_1 + 20 * m_1 - 5 * ee + ff, \text{ or} \quad (8-241)$$

$$j_1 = aa - 5 * bb + 20 * b_1 + 20 * s_1 - 5 * gg + hh \quad (8-242)$$

where intermediate values denoted as aa, bb, gg, s_1 and hh are derived by applying the 6-tap filter horizontally in the same manner as the derivation of b_1 and intermediate values denoted as cc, dd, ee, m_1 and ff are derived by applying the 6-tap filter vertically in the same manner as the derivation of h_1 . The final prediction value j are derived using:

$$j = \text{Clip1}_Y((j_1 + 512) \ggg 10) \quad (8-243)$$

- The final prediction values s and m are derived from s_1 and m_1 in the same manner as the derivation of b and h, as given by:

$$s = \text{Clip1}_Y((s_1 + 16) \ggg 5) \quad (8-244)$$

$$m = \text{Clip1}_Y((m_1 + 16) \ggg 5) \quad (8-245)$$

- The samples at quarter sample positions labelled as a, c, d, n, f, i, k, and q are derived by averaging with upward rounding of the two nearest samples at integer and half sample positions using:

$$a = (G + b + 1) \ggg 1 \quad (8-246)$$

$$c = (H + b + 1) \ggg 1 \quad (8-247)$$

$$d = (G + h + 1) \ggg 1 \quad (8-248)$$

$$n = (M + h + 1) \ggg 1 \quad (8-249)$$

$$f = (b + j + 1) \ggg 1 \quad (8-250)$$

$$i = (h + j + 1) \ggg 1 \quad (8-251)$$

$$k = (j + m + 1) \ggg 1 \quad (8-252)$$

$$q = (j + s + 1) \ggg 1. \quad (8-253)$$

- The samples at quarter sample positions labelled as e, g, p, and r are derived by averaging with upward rounding of the two nearest samples at half sample positions in the diagonal direction using

$$e = (b + h + 1) \ggg 1 \quad (8-254)$$

$$g = (b + m + 1) \ggg 1 \quad (8-255)$$

$$p = (h + s + 1) \ggg 1 \quad (8-256)$$

$$r = (m + s + 1) \ggg 1. \quad (8-257)$$

The luma location offset in fractional-sample units ($x_{\text{Frac}_L}, y_{\text{Frac}_L}$) specifies which of the generated luma samples at full-sample and fractional-sample locations is assigned to the predicted luma sample value $\text{predPartLX}_L[x_L, y_L]$. This assignment is done according to Table 8-12. The value of $\text{predPartLX}_L[x_L, y_L]$ is the output.

Table 8-12 – Assignment of the luma prediction sample $\text{predPartLX}_L[x_L, y_L]$

$x\text{Frac}_L$	0	0	0	0	1	1	1	1	2	2	2	2	3	3	3	3
$y\text{Frac}_L$	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
$\text{predPartLX}_L[x_L, y_L]$	G	d	h	n	a	e	i	p	b	f	j	q	c	g	k	r

8.4.2.2.2 Chroma sample interpolation process

This process shall only be invoked when chroma_format_idc is not equal to 0 (monochrome).

Inputs to this process are

- a chroma location in full-sample units ($x\text{Int}_C, y\text{Int}_C$),
- a chroma location offset in fractional-sample units ($x\text{Frac}_C, y\text{Frac}_C$), and
- chroma component samples from the selected reference picture refPicLX_C .

Output of this process is a predicted chroma sample value $\text{predPartLX}_C[x_C, y_C]$.

In Figure 8-5, the positions labelled with A, B, C, and D represent chroma samples at full-sample locations inside the given two-dimensional array refPicLX_C of chroma samples.

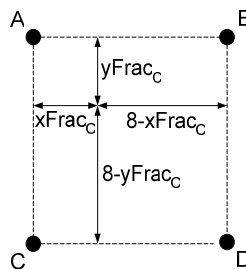


Figure 8-5 – Fractional sample position dependent variables in chroma interpolation and surrounding integer position samples A, B, C, and D

The variable $\text{refPicHeightEffective}_C$, which is the height of the effective reference picture chroma array, is derived as follows.

- If MbaffFrameFlag is equal to 0 or $\text{mb_field_decoding_flag}$ is equal to 0, $\text{refPicHeightEffective}_C$ is set equal to $\text{PicHeightInSamples}_C$.
- Otherwise (MbaffFrameFlag is equal to 1 and $\text{mb_field_decoding_flag}$ is equal to 1), $\text{refPicHeightEffective}_C$ is set equal to $\text{PicHeightInSamples}_C / 2$.

The sample coordinates specified in Equations 8-258 through 8-265 are used for generating the predicted chroma sample value $\text{predPartLX}_C[x_C, y_C]$.

$$xA_C = \text{Clip3}(0, \text{PicWidthInSamples}_C - 1, x\text{Int}_C) \quad (8-258)$$

$$xB_C = \text{Clip3}(0, \text{PicWidthInSamples}_C - 1, x\text{Int}_C + 1) \quad (8-259)$$

$$xC_C = \text{Clip3}(0, \text{PicWidthInSamples}_C - 1, x\text{Int}_C) \quad (8-260)$$

$$xD_C = \text{Clip3}(0, \text{PicWidthInSamples}_C - 1, x\text{Int}_C + 1) \quad (8-261)$$

$$yA_C = \text{Clip3}(0, \text{refPicHeightEffective}_C - 1, y\text{Int}_C) \quad (8-262)$$

$$yB_C = \text{Clip3}(0, \text{refPicHeightEffective}_C - 1, y\text{Int}_C) \quad (8-263)$$

$$yC_C = \text{Clip3}(0, \text{refPicHeightEffective}_C - 1, y\text{Int}_C + 1) \quad (8-264)$$

$$yD_C = \text{Clip3}(0, \text{refPicHeightEffective}_C - 1, y\text{Int}_C + 1) \quad (8-265)$$

Given the chroma samples A, B, C, and D at full-sample locations specified in Equations 8-258 through 8-265, the predicted chroma sample value $\text{predPartLX}_C[x_C, y_C]$ is derived as follows:

$$\text{predPartLX}_C[x_C, y_C] = ((8 - x_{\text{Frac}_C}) * (8 - y_{\text{Frac}_C}) * A + x_{\text{Frac}_C} * (8 - y_{\text{Frac}_C}) * B + (8 - x_{\text{Frac}_C}) * y_{\text{Frac}_C} * C + x_{\text{Frac}_C} * y_{\text{Frac}_C} * D + 32) \gg 6 \quad (8-266)$$

8.4.2.3 Weighted sample prediction process

Inputs to this process are

- mbPartIdx : the current partition given by the partition index
- subMbPartIdx : the sub-macroblock partition index
- predFlagL0 and predFlagL1 : prediction list utilization flags
- predPartLX_L : a $(\text{partWidth}) \times (\text{partHeight})$ array of prediction luma samples (with LX being replaced by L0 or L1 depending on predFlagL0 and predFlagL1)
- when chroma_format_idc is not equal to 0 (monochrome), predPartLX_{Cb} and predPartLX_{Cr} : $(\text{partWidthC}) \times (\text{partHeightC})$ arrays of prediction chroma samples, one for each of the chroma components Cb and Cr (with LX being replaced by L0 or L1 depending on predFlagL0 and predFlagL1)

Outputs of this process are

- predPart_L : a $(\text{partWidth}) \times (\text{partHeight})$ array of prediction luma samples and
- when chroma_format_idc is not equal to 0 (monochrome), predPart_{Cb} , and predPart_{Cr} : $(\text{partWidthC}) \times (\text{partHeightC})$ arrays of prediction chroma samples, one for each of the chroma components Cb and Cr.

For macroblocks or partitions with predFlagL0 equal to 1 in P and SP slices, the following applies.

- If $\text{weighted_pred_flag}$ is equal to 0, the default weighted sample prediction process as described in subclause 8.4.2.3.1 is invoked with the same inputs and outputs as the process described in this subclause.
- Otherwise ($\text{weighted_pred_flag}$ is equal to 1), the explicit weighted prediction process as described in subclause 8.4.2.3.2 is invoked with the same inputs and outputs as the process described in this subclause.

For macroblocks or partitions with predFlagL0 or predFlagL1 equal to 1 in B slices, the following applies.

- If $\text{weighted_bipred_idc}$ is equal to 0, the default weighted sample prediction process as described in subclause 8.4.2.3.1 is invoked with the same inputs and outputs as the process described in this subclause.
- Otherwise, if $\text{weighted_bipred_idc}$ is equal to 1, the explicit weighted sample prediction process as described in subclause 8.4.2.3.2, for macroblocks or partitions with predFlagL0 or predFlagL1 equal to 1 with the same inputs and outputs as the process described in this subclause.
- Otherwise ($\text{weighted_bipred_idc}$ is equal to 2), the following applies.
 - If predFlagL0 is equal to 1 and predFlagL1 is equal to 1, the implicit weighted sample prediction as described in subclause 8.4.2.3.2 is invoked with the same inputs and outputs as the process described in this subclause.
 - Otherwise (predFlagL0 or predFlagL1 are equal to 1 but not both), the default weighted sample prediction process as described in subclause 8.4.2.3.1 is invoked with the same inputs and outputs as the process described in this subclause.

8.4.2.3.1 Default weighted sample prediction process

Input to this process are the same as specified in subclause 8.4.2.3.

Output of this process are the same as specified in subclause 8.4.2.3.

Depending on the available component for which the prediction block is derived, the following applies.

- If the luma sample prediction values $\text{predPart}_L[x, y]$ are derived, the following applies with C set equal to L, x set equal to 0 .. $\text{partWidth} - 1$, and y set equal to 0 .. $\text{partHeight} - 1$.
- Otherwise, if the chroma Cb component sample prediction values $\text{predPart}_{Cb}[x, y]$ are derived, the following applies with C set equal to Cb, x set equal to 0 .. $\text{partWidthC} - 1$, and y set equal to 0 .. $\text{partHeightC} - 1$.
- Otherwise (the chroma Cr component sample prediction values $\text{predPart}_{Cr}[x, y]$ are derived), the following applies with C set equal to Cr, x set equal to 0 .. $\text{partWidthC} - 1$, and y set equal to 0 .. $\text{partHeightC} - 1$.

The prediction sample values are derived as follows.

- If predFlagL0 is equal to 1 and predFlagL1 is equal to 0 for the current partition

$$\text{predPart}_c[x, y] = \text{predPartL0}_c[x, y] \quad (8-267)$$

- Otherwise, if predFlagL0 is equal to 0 and predFlagL1 is equal to 1 for the current partition

$$\text{predPart}_c[x, y] = \text{predPartL1}_c[x, y] \quad (8-268)$$

- Otherwise (predFlagL0 and predFlagL1 are equal to 1 for the current partition),

$$\text{predPart}_c[x, y] = (\text{predPartL0}_c[x, y] + \text{predPartL1}_c[x, y] + 1) \gg 1. \quad (8-269)$$

8.4.2.3.2 Weighted sample prediction process

Input to this process are the same as specified in subclause 8.4.2.3.

Output of this process are the same as specified in subclause 8.4.2.3.

Depending on the available component for which the prediction block is derived, the following applies.

- If the luma sample prediction values $\text{predPart}_L[x, y]$ are derived, the following applies with C set equal to L, x set equal to 0 .. partWidth - 1, and y set equal to 0 .. partHeight - 1.
- Otherwise, if the chroma Cb component sample prediction values $\text{predPart}_{Cb}[x, y]$ are derived, the following applies with C set equal to Cb, x set equal to 0 .. partWidthC - 1, and y set equal to 0 .. partHeightC - 1.
- Otherwise (the chroma Cr component sample prediction values $\text{predPart}_{Cr}[x, y]$ are derived), the following applies with C set equal to Cr, x set equal to 0 .. partWidthC - 1, and y set equal to 0 .. partHeightC - 1.

The prediction sample values are derived as follows

- If the partition mbPartIdx\subMbPartIdx has predFlagL0 equal to 1 and predFlagL1 equal to 0, the final predicted sample values $\text{predPart}_c[x, y]$ are derived by

$$\begin{aligned} &\text{if}(\log\text{WD} \geq 1) \\ &\quad \text{predPart}_c[x, y] = \text{Clip1}_c((\text{predPartL0}_c[x, y] * w_0 + 2^{\log\text{WD}-1}) \gg \log\text{WD}) + o_0) \\ &\quad \text{else} \\ &\quad \text{predPart}_c[x, y] = \text{Clip1}_c(\text{predPartL0}_c[x, y] * w_0 + o_0) \end{aligned} \quad (8-270)$$

- Otherwise, if the partition mbPartIdx\subMbPartIdx has predFlagL0 equal to 0 and predFlagL1 equal to 1, the final predicted sample values $\text{predPart}_c[x, y]$ are derived by

$$\begin{aligned} &\text{if}(\log\text{WD} \geq 1) \\ &\quad \text{predPart}_c[x, y] = \text{Clip1}_c((\text{predPartL1}_c[x, y] * w_1 + 2^{\log\text{WD}-1}) \gg \log\text{WD}) + o_1) \\ &\quad \text{else} \\ &\quad \text{predPart}_c[x, y] = \text{Clip1}_c(\text{predPartL1}_c[x, y] * w_1 + o_1) \end{aligned} \quad (8-271)$$

- Otherwise (the partition mbPartIdx\subMbPartIdx has both predFlagL0 and predFlagL1 equal to 1), the final predicted sample values $\text{predPart}_c[x, y]$ are derived by

$$\text{predPart}_c[x, y] = \text{Clip1}_c(((\text{predPartL0}_c[x, y] * w_0 + \text{predPartL1}_c[x, y] * w_1 + 2^{\log\text{WD}}) \gg (\log\text{WD} + 1)) + ((o_0 + o_1 + 1) \gg 1)) \quad (8-272)$$

The variables in the above derivation for the prediction samples are derived as follows.

- If weighted_bipred_idc is equal to 2 and the slice_type is equal to B, implicit mode weighted prediction is used as follows.

$$\log\text{WD} = 5 \quad (8-273)$$

$$o_0 = 0 \quad (8-274)$$

$$o_1 = 0 \quad (8-275)$$

and w_0 and w_1 are derived as follows.

- The variables currPicOrField, pic0, and pic1 are derived as follows:
 - If field_pic_flag is equal to 0 and the current macroblock is a field macroblock, the following applies.
 - currPicOrField is the field of the current picture CurrPic that has the same parity as the current macroblock.
 - The variable pic0 is derived as follows.
 - If refIdxL0 % 2 is equal to 0, pic0 is the field of RefPicList0[refIdxL0 / 2] that has the same parity as the current macroblock.
 - Otherwise (refIdxL0 % 2 is not equal to 0), pic0 is the field of RefPicList0[refIdxL0 / 2] that has the opposite parity of the current macroblock.
 - The variable pic1 is derived as follows.
 - If refIdxL1 % 2 is equal to 0, pic1 is the field of RefPicList1[refIdxL1 / 2] that has the same parity as the current macroblock.
 - Otherwise (refIdxL1 % 2 is not equal to 0), pic1 is the field of RefPicList1[refIdxL1 / 2] that has the opposite parity of the current macroblock.
 - Otherwise (field_pic_flag is equal to 1 or the current macroblock is a frame macroblock), currPicOrField is the current picture CurrPic, pic1 is RefPicList1[refIdxL1], and pic0 is RefPicList0[refIdxL0].
- The variables tb, td, tx, and DistScaleFactor are derived from the values of currPicOrField, pic0, pic1 using Equations 8-198, 8-199, 8-194, and 8-195, respectively.
- If DiffPicOrderCnt(pic1, pic0) is equal to 0 or one or both of pic1 and pic0 is marked as "used for long-term reference" or (DistScaleFactor >> 2) < -64 or (DistScaleFactor >> 2) > 128, w_0 and w_1 are derived as

$$w_0 = 32 \quad (8-276)$$

$$w_1 = 32 \quad (8-277)$$

– Otherwise,

$$w_0 = 64 - (\text{DistScaleFactor} \gg 2) \quad (8-278)$$

$$w_1 = \text{DistScaleFactor} \gg 2 \quad (8-279)$$

- Otherwise (weighted_pred_flag is equal to 1 in P or SP slices or weighted_bipred_idc equal to 1 in B slices), explicit mode weighted prediction is used as follows.

- The variables refIdxL0WP and refIdxL1WP are derived as follows.

- If MbaffFrameFlag is equal to 1 and the current macroblock is a field macroblock

$$\text{refIdxL0WP} = \text{refIdxL0} \gg 1 \quad (8-280)$$

$$\text{refIdxL1WP} = \text{refIdxL1} \gg 1 \quad (8-281)$$

- Otherwise (MbaffFrameFlag is equal to 0 or the current macroblock is a frame macroblock),

$$\text{refIdxL0WP} = \text{refIdxL0} \quad (8-282)$$

$$\text{refIdxL1WP} = \text{refIdxL1} \quad (8-283)$$

– The variables logWD, w_0 , w_1 , o_0 , and o_1 are derived as follows.

– If C in $\text{predPart}_C[x, y]$ is replaced by L for luma samples

$$\text{logWD} = \text{luma_log2_weight_denom} \quad (8-284)$$

$$w_0 = \text{luma_weight_10}[\text{refIdxL0WP}] \quad (8-285)$$

$$w_1 = \text{luma_weight_11}[\text{refIdxL1WP}] \quad (8-286)$$

$$o_0 = \text{luma_offset_10}[\text{refIdxL0WP}] * (1 \ll (\text{BitDepth}_Y - 8)) \quad (8-287)$$

$$o_1 = \text{luma_offset_11}[\text{refIdxL1WP}] * (1 \ll (\text{BitDepth}_Y - 8)) \quad (8-288)$$

– Otherwise (C in $\text{predPart}_C[x, y]$ is replaced by Cb or Cr for chroma samples, with $iCbCr = 0$ for Cb, $iCbCr = 1$ for Cr),

$$\text{logWD} = \text{chroma_log2_weight_denom} \quad (8-289)$$

$$w_0 = \text{chroma_weight_10}[\text{refIdxL0WP}][iCbCr] \quad (8-290)$$

$$w_1 = \text{chroma_weight_11}[\text{refIdxL1WP}][iCbCr] \quad (8-291)$$

$$o_0 = \text{chroma_offset_10}[\text{refIdxL0WP}][iCbCr] * (1 \ll (\text{BitDepth}_C - 8)) \quad (8-292)$$

$$o_1 = \text{chroma_offset_11}[\text{refIdxL1WP}][iCbCr] * (1 \ll (\text{BitDepth}_C - 8)) \quad (8-293)$$

When explicit mode weighted prediction is used and the partition $\text{mbPartIdx} \setminus \text{subMbPartIdx}$ has both predFlagL0 and predFlagL1 equal to 1, the following constraint shall be obeyed

$$-128 \leq w_0 + w_1 \leq ((\text{logWD} == 7) ? 127 : 128) \quad (8-294)$$

NOTE – For implicit mode weighted prediction, weights w_0 and w_1 are each guaranteed to be in the range of -64..128 and the constraint expressed in Equation 8-294, although not explicitly imposed, will always be met. For explicit mode weighted prediction with logWD equal to 7, when one of the two weights w_0 or w_1 is inferred to be equal to 128 (as a consequence of $\text{luma_weight_10_flag}$, $\text{luma_weight_11_flag}$, $\text{chroma_weight_10_flag}$, or $\text{chroma_weight_11_flag}$ equal to 0), the other weight (w_1 or w_0) must have a negative value in order for the constraint expressed in Equation 8-294 to hold (and therefore the other flag $\text{luma_weight_10_flag}$, $\text{luma_weight_11_flag}$, $\text{chroma_weight_10_flag}$, or $\text{chroma_weight_11_flag}$ must be equal to 1).

8.5 Transform coefficient decoding process and picture construction process prior to deblocking filter process

Inputs to this process are Intra16x16DCLevel (if available), Intra16x16ACLevel (if available), LumaLevel (if available), LumaLevel8x8 (if available), ChromaDCLevel (if available), ChromaACLevel (if available), and available Inter or Intra prediction sample arrays for the current macroblock for the applicable components pred_L , pred_{Cb} , or pred_{Cr} .

NOTE 1 – When decoding a macroblock in Intra_4x4 (or Intra_8x8) prediction mode, the luma component of the macroblock prediction array may not be complete, since for each $4x4$ (or $8x8$) luma block, the Intra_4x4 (or Intra_8x8) prediction process for luma samples as specified in subclause 8.3.1 (or 8.3.2) and the process specified in this subclause are iterated.

Outputs of this process are the constructed sample arrays prior to the deblocking filter process for the applicable components S'_L , S'_{Cb} , or S'_{Cr} .

NOTE 2 – When decoding a macroblock in Intra_4x4 (or Intra_8x8) prediction mode, the luma component of the macroblock constructed sample arrays prior to the deblocking filter process may not be complete, since for each $4x4$ (or $8x8$) luma block, the

Intra_4x4 (or Intra_8x8) prediction process for luma samples as specified in subclause 8.3.1 (or 8.3.2) and the process specified in this subclause are iterated.

This subclause specifies transform coefficient decoding and picture construction prior to the deblocking filter process.

When the current macroblock is coded as P_Skip or B_Skip, all values of LumaLevel, LumaLevel8x8, ChromaDCLLevel, ChromaACLLevel are set equal to 0 for the current macroblock.

When residual_colour_transform_flag is equal to 1, the residual colour transform process as specified in subclause 8.5.13 is invoked.

8.5.1 Specification of transform decoding process for 4x4 luma residual blocks

This specification applies when transform_size_8x8_flag is equal to 0.

When the current macroblock prediction mode is not equal to Intra_16x16, the variable LumaLevel contains the levels for the luma transform coefficients. For a 4x4 luma block indexed by luma4x4BlkIdx = 0..15, the following ordered steps are specified.

1. The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with LumaLevel[luma4x4BlkIdx] as the input and the two-dimensional array c as the output.
2. The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with c as the input and r as the output.
3. When residual_colour_transform_flag is equal to 1, the variable $R_{Y,ij}$ is set equal to r_{ij} with $i, j = 0..3$ and this process is suspended until after completion of the residual colour transform process as specified in subclause 8.5.13, after the completion of which, the variable r_{ij} is set equal to $R_{G,ij}$ with $i, j = 0..3$ and this process is continued.
4. The position of the upper-left sample of a 4x4 luma block with index luma4x4BlkIdx inside the macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with luma4x4BlkIdx as the input and the output being assigned to (xO, yO).
5. The 4x4 array u with elements u_{ij} for $i, j = 0..3$ is derived as

$$u_{ij} = \text{Clip1}_Y(\text{pred}_L[xO + j, yO + i] + r_{ij}) \quad (8-295)$$

When qpprime_y_zero_transform_bypass_flag is equal to 1 and QP'_Y is equal to 0, the bitstream shall not contain data that result in a value of u_{ij} as computed by Equation 8-295 that is not equal to $\text{pred}_L[xO + j, yO + i] + r_{ij}$.

6. The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with luma4x4BlkIdx and u as the inputs.

8.5.2 Specification of transform decoding process for luma samples of Intra_16x16 macroblock prediction mode

When the current macroblock prediction mode is equal to Intra_16x16, the variables Intra16x16DCLLevel and Intra16x16ACLLevel contain the levels for the luma transform coefficients. The transform coefficient decoding proceeds in the following ordered steps:

1. The 4x4 luma DC transform coefficients of all 4x4 luma blocks of the macroblock are decoded.
 - a. The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with Intra16x16DCLLevel as the input and the two-dimensional array c as the output.
 - b. The scaling and transformation process for luma DC transform coefficients for Intra_16x16 macroblock type as specified in subclause 8.5.8 is invoked with c as the input and dcY as the output.
2. For a 4x4 luma block indexed by luma4x4BlkIdx = 0..15, the following ordered steps are specified.
 - a. The variable lumaList, which is a list of 16 entries, is derived. The first entry of lumaList is the corresponding value from the array dcY. Figure 8-6 shows the assignment of the indices of the array dcY to the luma4x4BlkIdx. The two numbers in the small squares refer to indices i and j in dcY_{ij} , and the numbers in large squares refer to luma4x4BlkIdx.

⁰⁰ 0	⁰¹ 1	⁰² 4	⁰³ 5
¹⁰ 2	¹¹ 3	¹² 6	¹³ 7
²⁰ 8	²¹ 9	²² 12	²³ 13
³⁰ 10	³¹ 11	³² 14	³³ 15

Figure 8-6 – Assignment of the indices of dcY to luma4x4BlkIdx

The elements in lumaList with index $k = 1..15$ are specified as

$$\text{lumaList}[k] = \text{Intra16x16ACLevel}[\text{luma4x4BlkIdx}][k - 1] \quad (8-296)$$

- b. The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with lumaList as the input and the two-dimensional array c as the output.
- c. The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with c as the input and r as the output.
- d. When residual_colour_transform_flag is equal to 1, the variable $R_{Y,ij}$ is set equal to r_{ij} with $i, j = 0..3$ and this process is suspended until after completion of the residual colour transform process as specified in subclause 8.5.13, after the completion of which, the variable r_{ij} is set equal to $R_{G,ij}$ with $i, j = 0..3$ and this process is continued.
- e. The position of the upper-left sample of a 4x4 luma block with index luma4x4BlkIdx inside the macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with luma4x4BlkIdx as the input and the output being assigned to (xO, yO).
- f. The 4x4 array u with elements u_{ij} for $i, j = 0..3$ is derived as

$$u_{ij} = \text{Clip1}_Y(\text{pred}_L[xO + j, yO + i] + r_{ij}) \quad (8-297)$$

When qpprime_y_zero_transform_bypass_flag is equal to 1 and QP'_Y is equal to 0, the bitstream shall not contain data that result in a value of u_{ij} as computed by 8-297 that is not equal to $\text{pred}_L[xO + j, yO + i] + r_{ij}$.

- g. The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with luma4x4BlkIdx and u as the inputs.

8.5.3 Specification of transform decoding process for 8x8 luma residual blocks

This specification applies when transform_size_8x8_flag is equal to 1.

The variable LumaLevel8x8[luma8x8BlkIdx] with luma8x8BlkIdx = 0..3 contains the levels for the luma transform coefficients for the luma 8x8 block with index luma8x8BlkIdx.

For an 8x8 luma block indexed by luma8x8BlkIdx = 0..3, the following ordered steps are specified.

1. The inverse scanning process for 8x8 luma transform coefficients as described in subclause 8.5.6 is invoked with LumaLevel8x8[luma8x8BlkIdx] as the input and the two-dimensional array c as the output.
2. The scaling and transformation process for residual 8x8 blocks as specified in subclause 8.5.11 is invoked with c as the input and r as the output.
3. When residual_colour_transform_flag is equal to 1, the variable $R_{Y,ij}$ is set equal to r_{ij} with $i, j = 0..7$ and this process is suspended until after completion of the residual colour transform process as specified in subclause 8.5.13, after the completion of which, the variable r_{ij} is set equal to $R_{G,ij}$ with $i, j = 0..7$ and this process is continued.

4. The position of the upper-left sample of an 8x8 luma block with index luma8x8BlkIdx inside the macroblock is derived by invoking the inverse 8x8 luma block scanning process in subclause 6.4.4 with luma8x8BlkIdx as the input and the output being assigned to (xO, yO).
5. The 8x8 array u with elements u_{ij} for i, j = 0..7 is derived as

$$u_{ij} = \text{Clip}_{1_Y}(\text{pred}_L[xO + j, yO + i] + r_{ij}) \quad (8-298)$$

When qpprime_y_zero_transform_bypass_flag is equal to 1 and QP'_Y is equal to 0, the bitstream shall not contain data that result in a value of u_{ij} as computed by Equation 8-298 that is not equal to pred_L[xO + j, yO + i] + r_{ij}.

6. The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with luma8x8BlkIdx and u as the inputs.

8.5.4 Specification of transform decoding process for chroma samples

This process is invoked for each chroma component Cb and Cr separately.

For each chroma component, the variables ChromaDCLevel[iCbCr] and ChromaACLevel[iCbCr], with iCbCr set equal to 0 for Cb and iCbCr set equal to 1 for Cr, contain the levels for both components of the chroma transform coefficients.

Let the variable numChroma4x4Blks be set equal to (MbWidthC / 4) * (MbHeightC / 4).

For each chroma component, the transform decoding proceeds separately in the following ordered steps:

1. The numChroma4x4Blks chroma DC transform coefficients of the 4x4 chroma blocks of the component indexed by iCbCr of the macroblock are decoded.

- a. Depending on the variable chroma_format_idc, the following applies.
 - If chroma_format_idc is equal to 1, the 2x2 array c is derived using the inverse raster scanning process applied to ChromaDCLevel as follows

$$c = \begin{bmatrix} \text{ChromaDCLevel}[iCbCr][0] & \text{ChromaDCLevel}[iCbCr][1] \\ \text{ChromaDCLevel}[iCbCr][2] & \text{ChromaDCLevel}[iCbCr][3] \end{bmatrix} \quad (8-299)$$

- Otherwise, if chroma_format_idc is equal to 2, the 2x4 array c is derived using the inverse raster scanning process applied to ChromaDCLevel as follows

$$c = \begin{bmatrix} \text{ChromaDCL\o\l\l\l}[iCbCr][0] & \text{ChromaDCL\o\l\l\l}[iCbCr][2] \\ \text{ChromaDCL\o\l\l\l}[iCbCr][1] & \text{ChromaDCL\o\l\l\l}[iCbCr][5] \\ \text{ChromaDCL\o\l\l\l}[iCbCr][3] & \text{ChromaDCL\o\l\l\l}[iCbCr][6] \\ \text{ChromaDCL\o\l\l\l}[iCbCr][4] & \text{ChromaDCL\o\l\l\l}[iCbCr][7] \end{bmatrix} \quad (8-300)$$

- Otherwise (chroma_format_idc is equal to 3), the inverse scanning process for transform coefficients as specified in subclause 8.5.5 is invoked with ChromaDCLevel[iCbCr] as the input and the two-dimensional 4x4 array c as the output.

- b. The scaling and transformation process for chroma DC transform coefficients as specified in subclause 8.5.9 is invoked with c as the input and dcC as the output.

2. For each 4x4 chroma block indexed by chroma4x4BlkIdx = 0..numChroma4x4Blks – 1 of the component indexed by iCbCr, the following ordered steps are specified.

- a. The variable chromaList, which is a list of 16 entries, is derived. The first entry of chromaList is the corresponding value from the array dcC. Figure 8-7 shows the assignment of the indices of the array dcC to the chroma4x4BlkIdx. The two numbers in the small squares refer to indices i and j in dcC_{ij}, and the numbers in large squares refer to chroma4x4BlkIdx.

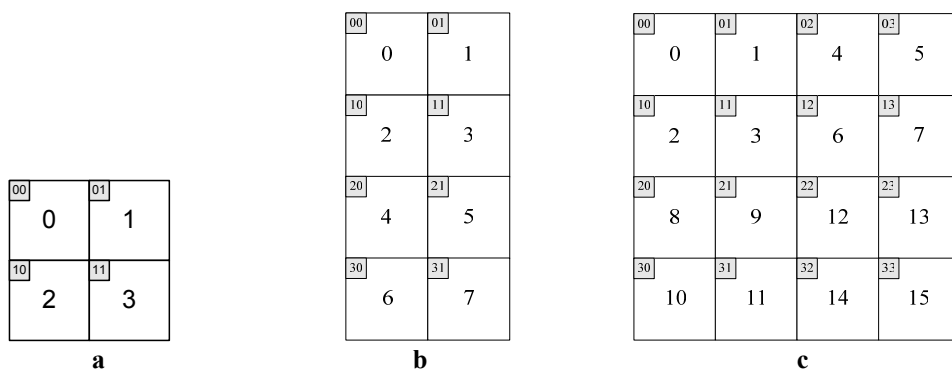


Figure 8-7 – Assignment of the indices of dcC to chroma4x4BlkIdx:
(a) chroma_format_idc equal to 1, (b) chroma_format_idc equal to 2, (c) chroma_format_idc equal to 3

The elements in chromaList with index $k = 1..15$ are specified as

$$\text{chromaList}[k] = \text{ChromaACLevel}[\text{chroma4x4BlkIdx}][k - 1] \quad (8-301)$$

- b. The inverse scanning process for transform coefficients as specified in subclause 8.5.9 is invoked with chromaList as the input and the two-dimensional array c as the output.
- c. The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with c as the input and r as the output.
- d. Depending on the variable chroma_format_idc, the position of the upper-left sample of a 4x4 chroma block with index chroma4x4BlkIdx inside the macroblock is derived as follows.

- If chroma_format_idc is equal to 1 or 2, the following applies.

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 0) \quad (8-302)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 1) \quad (8-303)$$

- Otherwise (chroma_format_idc is equal to 3), the following applies.

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 0) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 0) \quad (8-304)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 1) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 1) \quad (8-305)$$

- e. When residual_colour_transform_flag is equal to 1, the variable xO' is set equal to $xO \% (4 \ll \text{transform_size_8x8_flag})$, the variable yO' is set equal to $yO \% (4 \ll \text{transform_size_8x8_flag})$, and the following applies.
 - If this process is invoked for the chroma component Cb, the variable $R_{Cb,mn}$ is set equal to r_{ij} with $i, j = 0..3$, $m = xO' + i$, $n = yO' + j$, and this process is suspended until after completion of the residual colour transform process as specified in subclause 8.5.13, after which the variable r_{ij} is set equal to $R_{B,mn}$ with $i, j = 0..3$, $m = xO' + i$, $n = yO' + j$ and this process is continued.
 - Otherwise (this process is invoked for the chroma component Cr), the variable $R_{Cr,mn}$ is set equal to r_{ij} with $i, j = 0..3$, $m = xO' + i$, $n = yO' + j$ and this process is suspended until after the completion of the residual colour transform process as specified in subclause 8.5.13, after which the variable r_{ij} is set equal to $R_{R,mn}$ with $i, j = 0..3$, $m = xO' + i$, $n = yO' + j$ and this process is continued.
- f. The 4x4 array u with elements u_{ij} for $i, j = 0..3$ is derived as

$$u_{ij} = \text{Clip}_{1c}(\text{pred}_c[xO + j, yO + i] + r_{ij}) \quad (8-306)$$

When `qpprime_y_zero_transform_bypass_flag` is equal to 1 and QP'_Y is equal to 0, the bitstream shall not contain data that result in a value of u_{ij} as computed by Equation 8-306 that is not equal to $\text{pred}_c[xO + j, yO + i] + r_{ij}$.

- g. The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with `chroma4x4BlkIdx` and u as the inputs.

8.5.5 Inverse scanning process for transform coefficients

Input to this process is a list of 16 values.

Output of this process is a variable c containing a two-dimensional array of 4x4 values. In the case of transform coefficients, these 4x4 values represent levels assigned to locations in the transform block. In the case of applying the inverse scanning process to a scaling list, the output variable c contains a two-dimensional array representing a 4x4 scaling matrix.

The inverse scanning process for transform coefficients maps the sequence of transform coefficient levels to the transform coefficient level positions. Table 8-13 specifies the two mappings: inverse zig-zag scan and inverse field scan. The inverse zig-zag scan is used for transform coefficients in frame macroblocks and the inverse field scan is used for transform coefficients in field macroblocks.

The inverse scanning process for scaling lists maps the sequence of scaling list entries to the positions in the corresponding scaling matrix. For this mapping, the inverse zig-zag scan is used.

Figure 8-8 illustrates the scans.

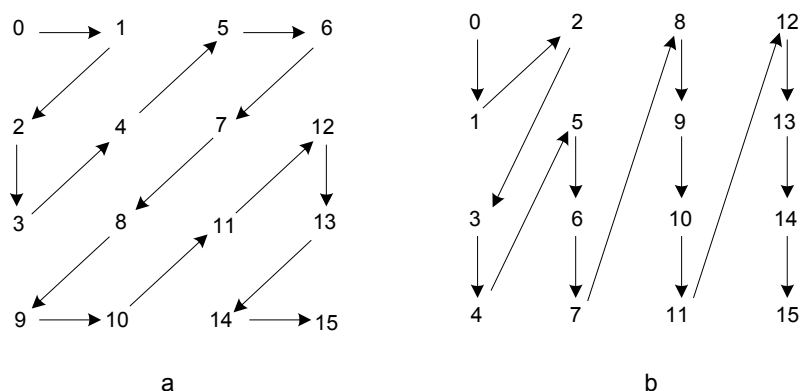


Figure 8-8 – 4x4 block scans. (a) Zig-zag scan. (b) Field scan (informative)

Table 8-13 provides the mapping from the index `idx` of input list of 16 elements to indices i and j of the two-dimensional array c .

Table 8-13 – Specification of mapping of `idx` to c_{ij} for zig-zag and field scan

idx	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
zig-zag	c_{00}	c_{01}	c_{10}	c_{20}	c_{11}	c_{02}	c_{03}	c_{12}	c_{21}	c_{30}	c_{31}	c_{22}	c_{13}	c_{23}	c_{32}	c_{33}
field	c_{00}	c_{10}	c_{01}	c_{20}	c_{30}	c_{11}	c_{21}	c_{31}	c_{02}	c_{12}	c_{22}	c_{32}	c_{03}	c_{13}	c_{23}	c_{33}

8.5.6 Inverse scanning process for 8x8 luma transform coefficients

Input to this process is a list of 64 values.

Output of this process is a variable *c* containing a two-dimensional array of 8x8 values. In the case of transform coefficients, these 8x8 values represent levels assigned to locations in the transform block. In the case of applying the inverse scanning process to a scaling list, the output variable *c* contains a two-dimensional array representing an 8x8 scaling matrix.

The inverse scanning process for transform coefficients maps the sequence of transform coefficient levels to the transform coefficient level positions. Table 8-14 specifies the two mappings: inverse 8x8 zig-zag scan and inverse 8x8 field scan. The inverse 8x8 zig-zag scan is used for transform coefficients in frame macroblocks and the inverse 8x8 field scan is used for transform coefficients in field macroblocks.

The inverse scanning process for scaling lists maps the sequence of scaling list entries to the positions in the corresponding scaling matrix. For this mapping, the inverse zig-zag scan is used.

Figure 8-9 illustrates the scans.

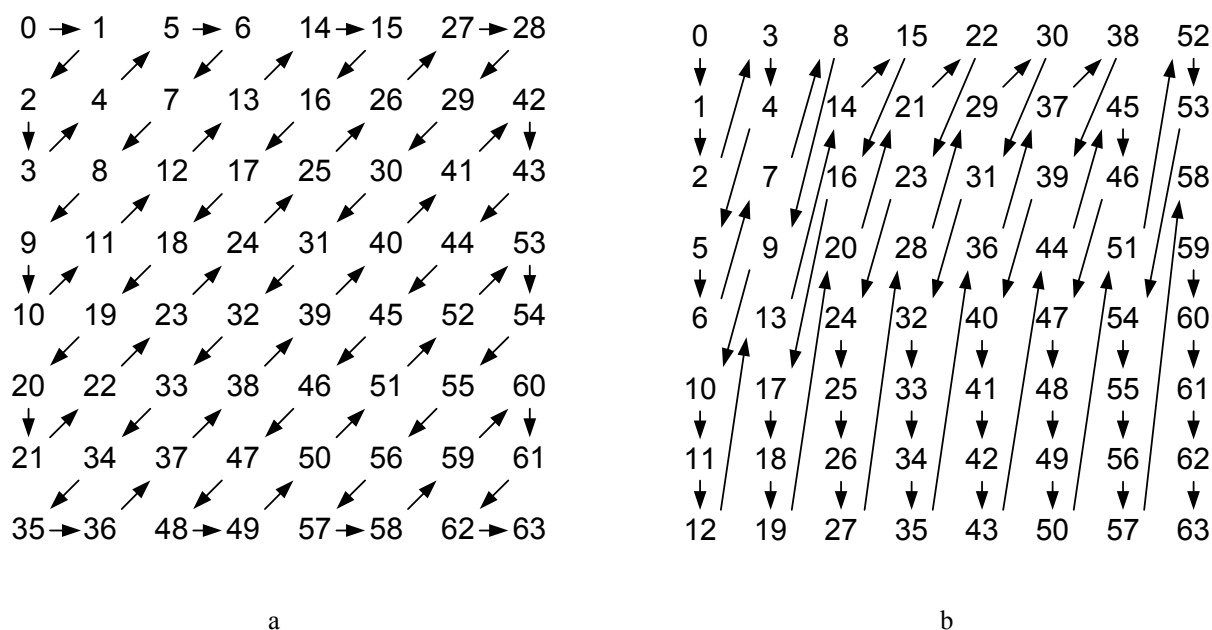


Figure 8-9 – 8x8 block scans. (a) 8x8 zig-zag scan. (b) 8x8 field scan (informative)

Table 8-14 provides the mapping from the index *idx* of the input list of 64 elements to indices *i* and *j* of the two-dimensional array *c*.

Table 8-14 – Specification of mapping of idx to c_{ij} for 8x8 zig-zag and 8x8 field scan

idx	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
zig-zag	c ₀₀	c ₀₁	c ₁₀	c ₂₀	c ₁₁	c ₀₂	c ₀₃	c ₁₂	c ₂₁	c ₃₀	c ₄₀	c ₃₁	c ₂₂	c ₁₃	c ₀₄	c ₀₅
field	c ₀₀	c ₁₀	c ₂₀	c ₀₁	c ₁₁	c ₃₀	c ₄₀	c ₂₁	c ₀₂	c ₃₁	c ₅₀	c ₆₀	c ₇₀	c ₄₁	c ₁₂	c ₀₃

Table 8-14 (continued) – Specification of mapping of idx to c_{ij} for 8x8 zig-zag and 8x8 field scan

idx	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
zig-zag	c ₁₄	c ₂₃	c ₃₂	c ₄₁	c ₅₀	c ₆₀	c ₅₁	c ₄₂	c ₃₃	c ₂₄	c ₁₅	c ₀₆	c ₀₇	c ₁₆	c ₂₅	c ₃₄
field	c ₂₂	c ₅₁	c ₆₁	c ₇₁	c ₃₂	c ₁₃	c ₀₄	c ₂₃	c ₄₂	c ₅₂	c ₆₂	c ₇₂	c ₃₃	c ₁₄	c ₀₅	c ₂₄

Table 8-14 (continued) – Specification of mapping of idx to c_{ij} for 8x8 zig-zag and 8x8 field scan

idx	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
zig-zag	c ₄₃	c ₅₂	c ₆₁	c ₇₀	c ₇₁	c ₆₂	c ₅₃	c ₄₄	c ₃₅	c ₂₆	c ₁₇	c ₂₇	c ₃₆	c ₄₅	c ₅₄	c ₆₃
field	c ₄₃	c ₅₃	c ₆₃	c ₇₃	c ₃₄	c ₁₅	c ₀₆	c ₂₅	c ₄₄	c ₅₄	c ₆₄	c ₇₄	c ₃₅	c ₁₆	c ₂₆	c ₄₅

Table 8-14 (concluded) – Specification of mapping of idx to c_{ij} for 8x8 zig-zag and 8x8 field scan

idx	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
zig-zag	c ₇₂	c ₇₃	c ₆₄	c ₅₅	c ₄₆	c ₃₇	c ₄₇	c ₅₆	c ₆₅	c ₇₄	c ₇₅	c ₆₆	c ₅₇	c ₆₇	c ₇₆	c ₇₇
field	c ₅₅	c ₆₅	c ₇₅	c ₃₆	c ₀₇	c ₁₇	c ₄₆	c ₅₆	c ₆₆	c ₇₆	c ₂₇	c ₃₇	c ₄₇	c ₅₇	c ₆₇	c ₇₇

8.5.7 Derivation process for the chroma quantisation parameters and scaling function

Outputs of this process are:

- QP_C: the chroma quantisation parameter for each chroma component Cb and Cr
- QS_C: the additional chroma quantisation parameter for each chroma component Cb and Cr required for decoding SP and SI slices (if applicable)

NOTE 1 – QP quantisation parameter values QP_Y and QS_Y are always in the range of –QpBdOffset_Y to 51, inclusive. QP quantisation parameter values QP_C and QS_C are always in the range of –QpBdOffset_C to 51, inclusive.

The value of QP_C for a chroma component is determined from the current value of QP_Y and the value of chroma_qp_index_offset (for Cb) or second_chroma_qp_index_offset (for Cr).

NOTE 2 – The scaling equations are specified such that the equivalent transform coefficient level scaling factor doubles for every increment of 6 in QP_Y. Thus, there is an increase in the factor used for scaling of approximately 12 % for each increase of 1 in the value of QP_Y.

The value of QP_C for each chroma component is determined as specified in Table 8-15 based on the index denoted as qP_I.

The variable qP_{Offset} for each chroma component is derived as follows.

- If the chroma component is the Cb component, qP_{Offset} is specified as

$$qP_{\text{Offset}} = \text{chroma_qp_index_offset} \quad (8-307)$$

- Otherwise (the chroma component is the Cr component), qP_{Offset} is specified as

$$qP_{\text{Offset}} = \text{second_chroma_qp_index_offset} \quad (8-308)$$

The value of qP_I for each chroma component is derived as

$$qP_I = \text{Clip3}(-QpBdOffset_C, 51, QP_Y + qP_{\text{Offset}}) \quad (8-309)$$

The value of QP'_C for the chroma components is derived as

$$QP'_C = QP_C + QpBdOffset_C \quad (8-310)$$

The value of $BitDepth'_C$ for the chroma components is derived as

$$BitDepth'_C = BitDepth_C + residual_colour_transform_flag \quad (8-311)$$

Table 8-15 – Specification of QP_C as a function of qP_1

qP_1	<30	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
QP_C	$=qP_1$	29	30	31	32	32	33	34	34	35	35	36	36	37	37	37	38	38	38	39	39	39	39

When the current slice is an SP or SI slice, QS_C is derived using the above process, substituting QP_Y with QS_Y and QP_C with QS_C .

The function $LevelScale(m, i, j)$ is specified as follows.

- The 4x4 matrix $weightScale(i, j)$ is specified as follows.
 - The variable $mbIsInterFlag$ is derived as follows.
 - If the current macroblock is coded using Inter macroblock prediction modes, $mbIsInterFlag$ is set equal to 1.
 - Otherwise (the current macroblock is coded using Intra macroblock prediction modes), $mbIsInterFlag$ is set equal to 0.
 - The variable $iYCbCr$ derived as follows.
 - If the input array c relates to a luma residual block, $iYCbCr$ is set equal to 0.
 - Otherwise, if the input array c relates to a chroma residual block and the chroma component is equal to Cb, $iYCbCr$ is set equal to 1.
 - Otherwise (the input array c relates to a chroma residual block and the chroma component is equal to Cr), $iYCbCr$ is set equal to 2.
- The inverse scanning process for transform coefficients as specified in subclause 8.5.5 is invoked with $ScalingList4x4[iYCbCr + ((mbIsInterFlag == 1) ? 3 : 0)]$ as the input and the output is assigned to the 4x4 matrix $weightScale$.

$$LevelScale(m, i, j) = weightScale(i, j) * normAdjust(m, i, j) \quad (8-312)$$

where

$$normAdjust(m, i, j) = \begin{cases} v_{m0} & \text{for } (i \% 2, j \% 2) \text{ equal to } (0,0), \\ v_{m1} & \text{for } (i \% 2, j \% 2) \text{ equal to } (1,1), \\ v_{m2} & \text{otherwise;} \end{cases} \quad (8-313)$$

where the first and second subscripts of v are row and column indices, respectively, of the matrix specified as:

$$v = \begin{bmatrix} 10 & 16 & 13 \\ 11 & 18 & 14 \\ 13 & 20 & 16 \\ 14 & 23 & 18 \\ 16 & 25 & 20 \\ 18 & 29 & 23 \end{bmatrix}. \quad (8-314)$$

The function $\text{LevelScale8x8}(m, i, j)$ is specified as follows:

- The 8x8 matrix $\text{weightScale8x8}(i, j)$ is specified as follows.
 - The variable mbIsInterFlag is derived as follows.
 - If the current macroblock is coded using Inter macroblock prediction modes, mbIsInterFlag is set equal to 1.
 - Otherwise (the current macroblock is coded using Intra macroblock prediction modes), mbIsInterFlag is set equal to 0.
- The inverse scanning process for 8x8 luma transform coefficients as specified in subclause 8.5.6 is invoked with $\text{ScalingList8x8}[\text{mbIsInterFlag}]$ as the input and the output is assigned to the 8x8 matrix weightScale8x8 .

$$\text{LevelScale8x8}(m, i, j) = \text{weightScale8x8}(i, j) * \text{normAdjust8x8}(m, i, j) \quad (8-315)$$

where

$$\text{normAdjust8x8}(m, i, j) = \begin{cases} v_{m0} & \text{for } (i \% 4, j \% 4) \text{ equal to } (0,0), \\ v_{m1} & \text{for } (i \% 2, j \% 2) \text{ equal to } (1,1), \\ v_{m2} & \text{for } (i \% 4, j \% 4) \text{ equal to } (2,2), \\ v_{m3} & \text{for } (i \% 4, j \% 2) \text{ equal to } (0,1) \text{ or } (i \% 2, j \% 4) \text{ equal to } (1,0), \\ v_{m4} & \text{for } (i \% 4, j \% 4) \text{ equal to } (0,2) \text{ or } (i \% 4, j \% 4) \text{ equal to } (2,0), \\ v_{m5} & \text{otherwise;} \end{cases} \quad (8-316)$$

where the first and second subscripts of v are row and column indices, respectively, of the matrix specified as:

$$v = \begin{bmatrix} 20 & 18 & 32 & 19 & 25 & 24 \\ 22 & 19 & 35 & 21 & 28 & 26 \\ 26 & 23 & 42 & 24 & 33 & 31 \\ 28 & 25 & 45 & 26 & 35 & 33 \\ 32 & 28 & 51 & 30 & 40 & 38 \\ 36 & 32 & 58 & 34 & 46 & 43 \end{bmatrix}. \quad (8-317)$$

8.5.8 Scaling and transformation process for luma DC transform coefficients for Intra_16x16 macroblock type

Inputs to this process are transform coefficient level values for luma DC transform coefficients of Intra_16x16 macroblocks as a 4x4 array c with elements c_{ij} , where i and j form a two-dimensional frequency index.

Outputs of this process are 16 scaled DC values for luma 4x4 blocks of Intra_16x16 macroblocks as a 4x4 array dcY with elements dcY_{ij} .

Depending on the values of $\text{qpprime_y_zero_transform_bypass_flag}$ and QP'_Y , the following applies.

- If $\text{qpprime_y_zero_transform_bypass_flag}$ is equal to 1 and QP'_Y is equal to 0, the output dcY is derived as

$$dcY_{ij} = c_{ij} \text{ with } i, j = 0..3 \quad (8-318)$$

- Otherwise ($\text{qpprime_y_zero_transform_bypass_flag}$ is equal to 0 or QP'_Y is not equal to 0), the following text of this process specifies the output.

The inverse transform for the 4x4 luma DC transform coefficients is specified by:

$$f = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \begin{bmatrix} c_{00} & c_{01} & c_{02} & c_{03} \\ c_{10} & c_{11} & c_{12} & c_{13} \\ c_{20} & c_{21} & c_{22} & c_{23} \\ c_{30} & c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \quad (8-319)$$

The bitstream shall not contain data that results in any element f_{ij} of f with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 1$, inclusive.

After the inverse transform, scaling is performed as follows.

- If QP'_Y is greater than or equal to 36, the scaled result is derived as

$$dcY_{ij} = (f_{ij} * \text{LevelScale}(QP'_Y \% 6, 0, 0)) \ll (QP'_Y / 6 - 6), \quad \text{with } i, j = 0..3 \quad (8-320)$$

- Otherwise (QP'_Y is less than 36), the scaled result is derived as

$$dcY_{ij} = (f_{ij} * \text{LevelScale}(QP'_Y \% 6, 0, 0) + 2^{5 - QP'_Y / 6}) \gg (6 - QP'_Y / 6), \quad \text{with } i, j = 0..3 \quad (8-321)$$

The bitstream shall not contain data that results in any element dcY_{ij} of dcY with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 1$, inclusive.

NOTE 1 – When `entropy_coding_mode_flag` is equal to 0 and QP'_Y is less than 10 and `profile_idc` is equal to 66, 77, or 88, the range of values that can be represented for the elements c_{ij} of c is not sufficient to represent the full range of values of the elements dcY_{ij} of dcY that could be necessary to form a close approximation of the content of any possible source picture by use of the `Intra_16x16` macroblock type.

NOTE 2 – Since the range limit imposed on the elements dcY_{ij} of dcY is imposed after the right shift in Equation 8-321, a larger range of values must be supported in the decoder prior to the right shift.

8.5.9 Scaling and transformation process for chroma DC transform coefficients

Inputs to this process are transform coefficient level values for chroma DC transform coefficients of one chroma component of the macroblock as an $(\text{MbWidthC} / 4) \times (\text{MbHeightC} / 4)$ array c with elements c_{ij} , where i and j form a two-dimensional frequency index.

Outputs of this process are the scaled DC values as an $(\text{MbWidthC} / 4) \times (\text{MbHeightC} / 4)$ array dcC with elements dcC_{ij} .

Depending on the values of `qpprime_y_zero_transform_bypass_flag` and QP'_Y , the following applies.

- If `qpprime_y_zero_transform_bypass_flag` is equal to 1 and QP'_Y is equal to 0, the output dcC is derived as

$$dcC_{ij} = c_{ij} \quad \text{with } i = 0..(\text{MbWidthC} / 4) - 1 \text{ and } j = 0..(\text{MbHeightC} / 4) - 1. \quad (8-322)$$

- Otherwise (`qpprime_y_zero_transform_bypass_flag` is equal to 0 or QP'_Y is not equal to 0), the following text of this process specifies the output.

Depending on the variable `chroma_format_idc`, the inverse transform is specified as follows.

- If `chroma_format_idc` is equal to 1, the inverse transform for the 2x2 chroma DC transform coefficients is specified as

$$f = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} c_{00} & c_{01} \\ c_{10} & c_{11} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (8-323)$$

- Otherwise, if `chroma_format_idc` is equal to 2, the inverse transform for the 2x4 chroma DC transform coefficients is specified as

$$f = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \begin{bmatrix} c_{00} & c_{01} \\ c_{10} & c_{11} \\ c_{20} & c_{21} \\ c_{30} & c_{31} \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (8-324)$$

– Otherwise (chroma_format_idc is equal to 3), the inverse transform for the 4x4 chroma DC transform coefficients is specified as follows.

– If residual_colour_transform_flag is equal to 1 and the current macroblock prediction mode MbPartPredMode(mb_type, 0) is Intra_4x4 or Intra_8x8, the inverse transform for the 4x4 chroma DC transform coefficients is specified as

$$f_{ij} = c_{ij} \ll 2 \quad \text{with } i, j = 0..3 \quad (8-325)$$

– Otherwise, the inverse transform for the 4x4 chroma DC transform coefficients is specified as

$$f = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \begin{bmatrix} c_{00} & c_{01} & c_{02} & c_{03} \\ c_{10} & c_{11} & c_{12} & c_{13} \\ c_{20} & c_{21} & c_{22} & c_{23} \\ c_{30} & c_{31} & c_{32} & c_{33} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1 & -1 & -1 \\ 1 & -1 & -1 & 1 \\ 1 & -1 & 1 & -1 \end{bmatrix} \quad (8-326)$$

The bitstream shall not contain data that results in any element f_{ij} of f with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}'_c)}$ to $2^{(7 + \text{BitDepth}'_c)} - 1$, inclusive.

After the inverse transform, scaling is performed depending on the variable chroma_format_idc as follows.

– If chroma_format_idc is equal to 1, the scaled result is derived as

$$dcC_{ij} = ((f_{ij} * \text{LevelScale}(QP'_C \% 6, 0, 0)) \ll (QP'_C / 6)) \gg 5, \quad \text{with } i, j = 0, 1 \quad (8-327)$$

– If chroma_format_idc is equal to 2, the following applies.

– The variable $QP'_{C,DC}$ is derived as

$$QP'_{C,DC} = QP'_C + 3 \quad (8-328)$$

– Depending on the value of $QP'_{C,DC}$, the following applies.

– If $QP'_{C,DC}$ is greater than or equal to 36, the scaled result is derived as

$$dcC_{ij} = (f_{ij} * \text{LevelScale}(QP'_{C,DC} \% 6, 0, 0)) \ll (QP'_{C,DC} / 6 - 6), \quad \text{with } i = 0..3, j = 0, 1 \quad (8-329)$$

– Otherwise ($QP'_{C,DC}$ is less than 36), the scaled result is derived as

$$dcC_{ij} = (f_{ij} * \text{LevelScale}(QP'_{C,DC} \% 6, 0, 0) + 2^{5 - QP'_{C,DC}/6}) \gg (6 - QP'_{C,DC} / 6), \quad \text{with } i = 0..3, j = 0, 1 \quad (8-330)$$

– Otherwise (chroma_format_idc is equal to 3), the following applies.

– If QP'_C is greater than or equal to 36, the scaled result is derived as

$$dcC_{ij} = (f_{ij} * \text{LevelScale}(QP'_C \% 6, 0, 0)) \ll (QP'_C / 6 - 6), \quad \text{with } i, j = 0..3. \quad (8-331)$$

– Otherwise (QP'_C is less than 36), the scaled result is derived as

$$dcC_{ij} = (f_{ij} * \text{LevelScale}(QP'_C \% 6, 0, 0) + 2^{5 - QP'_C/6}) \gg (6 - QP'_C / 6), \quad \text{with } i, j = 0..3 \quad (8-332)$$

The bitstream shall not contain data that results in any element dcC_{ij} of dcC with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}'_c)}$ to $2^{(7 + \text{BitDepth}'_c)} - 1$, inclusive.

NOTE 1 – When `entropy_coding_mode_flag` is equal to 0 and QP'_C is less than 4 and `profile_idc` is equal to 66, 77, or 88, the range of values that can be represented for the elements c_{ij} of c may not be sufficient to represent the full range of values of the elements dcC_{ij} of dcC that could be necessary to form a close approximation of the content of any possible source picture.

NOTE 2 – Since the range limit imposed on the elements dcC_{ij} of dcC is imposed after the right shift in Equation 8-327, 8-330, or 8-332, a larger range of values must be supported in the decoder prior to the right shift.

8.5.10 Scaling and transformation process for residual 4x4 blocks

Input to this process is a 4x4 array c with elements c_{ij} which is either an array relating to a residual block of the luma component or an array relating to a residual block of a chroma component.

Outputs of this process are residual sample values as 4x4 array r with elements r_{ij} .

Depending on the values of `qpprime_y_zero_transform_bypass_flag` and QP'_Y , the following applies.

- If `qpprime_y_zero_transform_bypass_flag` is equal to 1 and QP'_Y is equal to 0, the output r is derived as

$$r_{ij} = c_{ij} \text{ with } i, j = 0..3 \quad (8-333)$$

- Otherwise (`qpprime_y_zero_transform_bypass_flag` is equal to 0 or QP'_Y is not equal to 0), the following text of this process specifies the output.

The variable `bitDepth` is derived as follows.

- If the input array c relates to a luma residual block, `bitDepth` is set equal to `BitDepthY`.
- Otherwise (the input array c relates to a chroma residual block), `bitDepth` is set equal to `BitDepth'C`.

The bitstream shall not contain data that results in any element c_{ij} of c with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 1$, inclusive.

The variable `sMbFlag` is derived as follows.

- If `mb_type` is equal to SI or the macroblock prediction mode is equal to Inter in an SP slice, `sMbFlag` is set equal to 1,
- Otherwise (`mb_type` not equal to SI and the macroblock prediction mode is not equal to Inter in an SP slice), `sMbFlag` is set equal to 0.

The variable `qP` is derived as follows.

- If the input array c relates to a luma residual block and `sMbFlag` is equal to 0

$$qP = QP'_Y \quad (8-334)$$

- Otherwise, if the input array c relates to a luma residual block and `sMbFlag` is equal to 1

$$qP = QS_Y \quad (8-335)$$

- Otherwise, if the input array c relates to a chroma residual block and `sMbFlag` is equal to 0

$$qP = QP'_C \quad (8-336)$$

- Otherwise (the input array c relates to a chroma residual block and `sMbFlag` is equal to 1),

$$qP = QS_C \quad (8-337)$$

Scaling of 4x4 block transform coefficient levels c_{ij} proceeds as follows.

- If all of the following conditions are true
 - i is equal to 0
 - j is equal to 0
 - c relates to a luma residual block coded using `Intra_16x16` prediction mode or c relates to a chroma residual block

the variable d_{00} is derived by

$$d_{00} = c_{00} \quad (8-338)$$

– Otherwise, the following applies.

– If qP is greater than or equal to 24, the scaled result is derived as follows

$$d_{ij} = (c_{ij} * \text{LevelScale}(qP \% 6, i, j)) \ll (qP / 6 - 4), \text{ with } i, j = 0..3 \text{ except as noted above} \quad (8-339)$$

– Otherwise (qP is less than 24), the scaled result is derived as follows

$$d_{ij} = (c_{ij} * \text{LevelScale}(qP \% 6, i, j) + 2^{3-qP/6}) \gg (4 - qP / 6), \text{ with } i, j = 0..3 \text{ except as noted above} \quad (8-340)$$

The bitstream shall not contain data that results in any element d_{ij} of d with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 1$, inclusive.

The transform process shall convert the block of scaled transform coefficients to a block of output samples in a manner mathematically equivalent to the following.

First, each (horizontal) row of scaled transform coefficients is transformed using a one-dimensional inverse transform as follows.

A set of intermediate values is computed as follows.

$$e_{i0} = d_{i0} + d_{i2}, \text{ with } i = 0..3 \quad (8-341)$$

$$e_{i1} = d_{i0} - d_{i2}, \text{ with } i = 0..3 \quad (8-342)$$

$$e_{i2} = (d_{i1} \gg 1) - d_{i3}, \text{ with } i = 0..3 \quad (8-343)$$

$$e_{i3} = d_{i1} + (d_{i3} \gg 1), \text{ with } i = 0..3 \quad (8-344)$$

The bitstream shall not contain data that results in any element e_{ij} of e with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 1$, inclusive.

Then, the transformed result is computed from these intermediate values as follows.

$$f_{i0} = e_{i0} + e_{i3}, \text{ with } i = 0..3 \quad (8-345)$$

$$f_{i1} = e_{i1} + e_{i2}, \text{ with } i = 0..3 \quad (8-346)$$

$$f_{i2} = e_{i1} - e_{i2}, \text{ with } i = 0..3 \quad (8-347)$$

$$f_{i3} = e_{i0} - e_{i3}, \text{ with } i = 0..3 \quad (8-348)$$

The bitstream shall not contain data that results in any element f_{ij} of f with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 1$, inclusive.

Then, each (vertical) column of the resulting matrix is transformed using the same one-dimensional inverse transform as follows.

A set of intermediate values is computed as follows.

$$g_{0j} = f_{0j} + f_{2j}, \text{ with } j = 0..3 \quad (8-349)$$

$$g_{1j} = f_{0j} - f_{2j}, \text{ with } j = 0..3 \quad (8-350)$$

$$g_{2j} = (f_{1j} \gg 1) - f_{3j}, \text{ with } j = 0..3 \quad (8-351)$$

$$g_{3j} = f_{1j} + (f_{3j} \gg 1), \text{ with } j = 0..3 \quad (8-352)$$

The bitstream shall not contain data that results in any element g_{ij} of g with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 1$, inclusive.

Then, the transformed result is computed from these intermediate values as follows.

$$h_{0j} = g_{0j} + g_{3j}, \text{ with } j = 0..3 \quad (8-353)$$

$$h_{1j} = g_{1j} + g_{2j}, \text{ with } j = 0..3 \quad (8-354)$$

$$h_{2j} = g_{1j} - g_{2j}, \text{ with } j = 0..3 \quad (8-355)$$

$$h_{3j} = g_{0j} - g_{3j}, \text{ with } j = 0..3 \quad (8-356)$$

The bitstream shall not contain data that results in any element h_{ij} of h with $i, j = 0..3$ that exceeds the range of integer values from $-2^{(7 + \text{bitDepth})}$ to $2^{(7 + \text{bitDepth})} - 33$, inclusive.

After performing both the one-dimensional horizontal and the one-dimensional vertical inverse transforms to produce an array of transformed samples, the final constructed residual sample values is derived as

$$r_{ij} = (h_{ij} + 2^5) \gg 6 \text{ with } i, j = 0..3 \quad (8-357)$$

8.5.11 Scaling and transformation process for residual 8x8 luma blocks

Input to this process is an 8x8 array c with elements c_{ij} which is an array relating to an 8x8 residual block of the luma component.

Outputs of this process are residual sample values as 8x8 array r with elements r_{ij} .

Depending on the values of `qprime_y_zero_transform_bypass_flag` and QP'_Y , the following applies.

- If `qprime_y_zero_transform_bypass_flag` is equal to 1 and QP'_Y is equal to 0, the output r is derived as

$$r_{ij} = c_{ij} \text{ with } i, j = 0..7 \quad (8-358)$$

- Otherwise (`qprime_y_zero_transform_bypass_flag` is equal to 0 or QP'_Y is not equal to 0), the following text of this process specifies the output.

The bitstream shall not contain data that results in any element c_{ij} of c with $i, j = 0..7$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 1$, inclusive.

The scaling process for 8x8 block transform coefficient levels c_{ij} proceeds as follows.

- If QP'_Y is greater than or equal to 36, the scaled result is derived as

$$d_{ij} = (c_{ij} * \text{LevelScale8x8}(QP'_Y \% 6, i, j)) \ll (QP'_Y / 6 - 6), \text{ with } i, j = 0..7 \quad (8-359)$$

- Otherwise (QP'_Y is less than 36), the scaled result is derived as

$$d_{ij} = (c_{ij} * \text{LevelScale8x8}(QP'_Y \% 6, i, j)) + 2^{5-QP'_Y/6} \gg (6 - QP'_Y / 6), \text{ with } i, j = 0..7 \quad (8-360)$$

The bitstream shall not contain data that results in any element d_{ij} of d with $i, j = 0..7$ that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 1$, inclusive.

The transform process shall convert the block of scaled transform coefficients to a block of output samples in a manner mathematically equivalent to the following.

First, each (horizontal) row of scaled transform coefficients is transformed using a one-dimensional inverse transform as follows.

- A set of intermediate values e_{ij} is derived by

$$e_{i0} = d_{i0} + d_{i4}, \text{ with } i = 0..7 \quad (8-361)$$

$$e_{i1} = -d_{i3} + d_{i5} - d_{i7} - (d_{i7} \gg 1), \text{ with } i = 0..7 \quad (8-362)$$

$$e_{i2} = d_{i0} - d_{i4}, \text{ with } i = 0..7 \quad (8-363)$$

$$e_{i3} = d_{i1} + d_{i7} - d_{i3} - (d_{i3} \gg 1), \text{ with } i = 0..7 \quad (8-364)$$

$$e_{i4} = (d_{i2} \gg 1) - d_{i6}, \text{ with } i = 0..7 \quad (8-365)$$

$$e_{i5} = -d_{i1} + d_{i7} + d_{i5} + (d_{i5} \gg 1), \text{ with } i = 0..7 \quad (8-366)$$

$$e_{i6} = d_{i2} + (d_{i6} \gg 1), \text{ with } i = 0..7 \quad (8-367)$$

$$e_{i7} = d_{i3} + d_{i5} + d_{i1} + (d_{i1} \gg 1), \text{ with } i = 0..7 \quad (8-368)$$

- A second set of intermediate results f_{ij} is computed from the intermediate values e_{ij} as

$$f_{i0} = e_{i0} + e_{i6}, \text{ with } i = 0..7 \quad (8-369)$$

$$f_{i1} = e_{i1} + (e_{i7} \gg 2), \text{ with } i = 0..7 \quad (8-370)$$

$$f_{i2} = e_{i2} + e_{i4}, \text{ with } i = 0..7 \quad (8-371)$$

$$f_{i3} = e_{i3} + (e_{i5} \gg 2), \text{ with } i = 0..7 \quad (8-372)$$

$$f_{i4} = e_{i2} - e_{i4}, \text{ with } i = 0..7 \quad (8-373)$$

$$f_{i5} = (e_{i3} \gg 2) - e_{i5}, \text{ with } i = 0..7 \quad (8-374)$$

$$f_{i6} = e_{i0} - e_{i6}, \text{ with } i = 0..7 \quad (8-375)$$

$$f_{i7} = e_{i7} - (e_{i1} \gg 2), \text{ with } i = 0..7 \quad (8-376)$$

- Then, the transformed result g_{ij} is computed from these intermediate values f_{ij} as

$$g_{i0} = f_{i0} + f_{i7}, \text{ with } i = 0..7 \quad (8-377)$$

$$g_{i1} = f_{i2} + f_{i5}, \text{ with } i = 0..7 \quad (8-378)$$

$$g_{i2} = f_{i4} + f_{i3}, \text{ with } i = 0..7 \quad (8-379)$$

$$g_{i3} = f_{i6} + f_{i1}, \text{ with } i = 0..7 \quad (8-380)$$

$$g_{i4} = f_{i6} - f_{i1}, \text{ with } i = 0..7 \quad (8-381)$$

$$g_{i5} = f_{i4} - f_{i3}, \text{ with } i = 0..7 \quad (8-382)$$

$$g_{i6} = f_{i2} - f_{i5}, \text{ with } i = 0..7 \quad (8-383)$$

$$g_{i7} = f_{i0} - f_{i7}, \text{ with } i = 0..7 \quad (8-384)$$

Then, each (vertical) column of the resulting matrix is transformed using the same one-dimensional inverse transform as follows.

- A set of intermediate values h_{ij} is computed from the horizontally transformed value g_{ij} as

$$h_{0j} = g_{0j} + g_{4j}, \text{ with } j = 0..7 \quad (8-385)$$

$$h_{1j} = -g_{3j} + g_{5j} - g_{7j} - (g_{7j} \gg 1), \text{ with } j = 0..7 \quad (8-386)$$

$$h_{2j} = g_{0j} - g_{4j}, \text{ with } j = 0..7 \quad (8-387)$$

$$h_{3j} = g_{1j} + g_{7j} - g_{3j} - (g_{3j} \gg 1), \text{ with } j = 0..7 \quad (8-388)$$

$$h_{4j} = (g_{2j} \gg 1) - g_{6j}, \text{ with } j = 0..7 \quad (8-389)$$

$$h_{5j} = -g_{1j} + g_{7j} + g_{5j} + (g_{5j} \gg 1), \text{ with } j = 0..7 \quad (8-390)$$

$$h_{6j} = g_{2j} + (g_{6j} \gg 1), \text{ with } j = 0..7 \quad (8-391)$$

$$h_{7j} = g_{3j} + g_{5j} + g_{1j} + (g_{1j} \gg 1), \text{ with } j = 0..7 \quad (8-392)$$

- A second set of intermediate results k_{ij} is computed from the intermediate values h_{ij} as

$$k_{0j} = h_{0j} + h_{6j}, \text{ with } j = 0..7 \quad (8-393)$$

$$k_{1j} = h_{1j} + (h_{7j} \gg 2), \text{ with } j = 0..7 \quad (8-394)$$

$$k_{2j} = h_{2j} + h_{4j}, \text{ with } j = 0..7 \quad (8-395)$$

$$k_{3j} = h_{3j} + (h_{5j} \gg 2), \text{ with } j = 0..7 \quad (8-396)$$

$$k_{4j} = h_{2j} - h_{4j}, \text{ with } j = 0..7 \quad (8-397)$$

$$k_{5j} = (h_{3j} \gg 2) - h_{5j}, \text{ with } j = 0..7 \quad (8-398)$$

$$k_{6j} = h_{0j} - h_{6j}, \text{ with } j = 0..7 \quad (8-399)$$

$$k_{7j} = h_{7j} - (h_{1j} \gg 2), \text{ with } j = 0..7 \quad (8-400)$$

– Then, the transformed result m_{ij} is computed from these intermediate values k_{ij} as

$$m_{0j} = k_{0j} + k_{7j}, \text{ with } j = 0..7 \quad (8-401)$$

$$m_{1j} = k_{2j} + k_{5j}, \text{ with } j = 0..7 \quad (8-402)$$

$$m_{2j} = k_{4j} + k_{3j}, \text{ with } j = 0..7 \quad (8-403)$$

$$m_{3j} = k_{6j} + k_{1j}, \text{ with } j = 0..7 \quad (8-404)$$

$$m_{4j} = k_{6j} - k_{1j}, \text{ with } j = 0..7 \quad (8-405)$$

$$m_{5j} = k_{4j} - k_{3j}, \text{ with } j = 0..7 \quad (8-406)$$

$$m_{6j} = k_{2j} - k_{5j}, \text{ with } j = 0..7 \quad (8-407)$$

$$m_{7j} = k_{0j} - k_{7j}, \text{ with } j = 0..7 \quad (8-408)$$

The bitstream shall not contain data that results in any element e_{ij} , f_{ij} , g_{ij} , h_{ij} , or k_{ij} for i and j in the range of $0..7$, inclusive, that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 1$, inclusive.

The bitstream shall not contain data that results in any element m_{ij} for i and j in the range of $0..7$, inclusive, that exceeds the range of integer values from $-2^{(7 + \text{BitDepth}_Y)}$ to $2^{(7 + \text{BitDepth}_Y)} - 33$, inclusive.

After performing both the one-dimensional horizontal and the one-dimensional vertical inverse transforms to produce an array of transformed samples, the final constructed residual sample values are derived as

$$r_{ij} = (m_{ij} + 2^5) \gg 6 \text{ with } i, j = 0..7 \quad (8-409)$$

8.5.12 Picture construction process prior to deblocking filter process

Inputs to this process are

- luma4x4BlkIdx or chroma4x4BlkIdx or luma8x8BlkIdx
- a sample array u with elements u_{ij} which is either a 4x4 luma block or a 4x4 chroma block or an 8x8 luma block

The position of the upper-left luma sample of the current macroblock is derived by invoking the inverse macroblock scanning process in subclause 6.4.1 with CurrMbAddr as input and the output being assigned to (xP, yP) .

When u is a luma block, for each sample u_{ij} of the luma block, the following applies.

- Depending on the size of the block u , the following applies.
 - If u is an 4x4 luma block, the position of the upper-left sample of the 4x4 luma block with index luma4x4BlkIdx inside the macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with luma4x4BlkIdx as the input and the output being assigned to (xO, yO) , and the variable nE is set equal to 4.
 - Otherwise (u is an 8x8 luma block), the position of the upper-left sample of the 8x8 luma block with index luma8x8BlkIdx inside the macroblock is derived by invoking the inverse 8x8 luma block scanning process in subclause 6.4.4 with luma8x8BlkIdx as the input and the output being assigned to (xO, yO) , and the variable nE is set equal to 8.
- Depending on the variable MbaffFrameFlag and the current macroblock, the following applies.
 - If MbaffFrameFlag is equal to 1 and the current macroblock is a field macroblock

$$S'_L[xP + xO + j, yP + 2 * (yO + i)] = u_{ij} \text{ with } i, j = 0..nE - 1 \quad (8-410)$$

- Otherwise (MbaffFrameFlag is equal to 0 or the current macroblock is a frame macroblock),

$$S'_L[xP + xO + j, yP + yO + i] = u_{ij} \quad \text{with } i, j = 0..nE - 1 \quad (8-411)$$

When u is a chroma block, for each sample u_{ij} of the 4x4 chroma block, the following applies.

- The subscript C in the variable S'_C is replaced with C_b for the C_b chroma component and with C_r for the C_r chroma component.
- Depending on the variable `chroma_format_idc`, the position of the upper-left sample of a 4x4 chroma block with index `chroma4x4BlkIdx` inside the macroblock is derived as follows.
 - If `chroma_format_idc` is equal to 1 or 2, the following applies.

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 0) \quad (8-412)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 1) \quad (8-413)$$

- Otherwise (`chroma_format_idc` is equal to 3), the following applies.

$$xO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 0) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 0) \quad (8-414)$$

$$yO = \text{InverseRasterScan}(\text{chroma4x4BlkIdx} / 4, 8, 8, 16, 1) + \text{InverseRasterScan}(\text{chroma4x4BlkIdx} \% 4, 4, 4, 8, 1) \quad (8-415)$$

- Depending on the variable `MbaffFrameFlag` and the current macroblock, the following applies.

- If `MbaffFrameFlag` is equal to 1 and the current macroblock is a field macroblock

$$S'_C[(xP / \text{subWidthC}) + xO + j, ((yP + \text{SubHeightC} - 1) / \text{SubHeightC}) + 2 * (yO + i)] = u_{ij} \quad \text{with } i, j = 0..3 \quad (8-416)$$

- Otherwise (`MbaffFrameFlag` is equal to 0 or the current macroblock is a frame macroblock),

$$S'_C[(xP / \text{subWidthC}) + xO + j, (yP / \text{SubHeightC}) + yO + i] = u_{ij} \quad \text{with } i, j = 0..3 \quad (8-417)$$

8.5.13 Residual colour transform process

This process is invoked when `residual_colour_transform_flag` is equal to 1.

After invoking, this process is suspended until the derivation of $R_{Y,ij}$, $R_{C_b,ij}$, and $R_{C_r,ij}$ has been completed for $i, j = 0..ijMax$, where `ijMax` is specified as follows.

- If `transform_size_8x8_flag` is equal to 0, the variable `ijMax` is set equal to 3.
- Otherwise (`transform_size_8x8_flag` is equal to 1), the variable `ijMax` is set equal to 7.

At the resumption of this process, all values $R_{Y,ij}$, $R_{C_b,ij}$, and $R_{C_r,ij}$ with $i, j = 0..ijMax$ shall be available through prior invocations of the relevant processes specified in subclauses 8.5.1, 8.5.2, 8.5.3, or 8.5.4

For each $i, j = 0..ijMax$, the residual colour transform is computed as

$$t = R_{Y,ij} - (R_{C_b,ij} \ggg 1) \quad (8-418)$$

$$R_{G,ij} = t + R_{C_b,ij} \quad (8-419)$$

$$R_{B,ij} = t - (R_{C_r,ij} \ggg 1) \quad (8-420)$$

$$R_{R,ij} = R_{B,ij} + R_{C_r,ij} \quad (8-421)$$

NOTE – The residual colour transform is similar to the YCgCo transformation specified in Equations E-30 through E-33. However, the residual colour transform operates on the decoded residual difference data within the decoding process rather than operating as a post-processing step that is outside the decoding process specified in this Recommendation | International Standard.

8.6 Decoding process for P macroblocks in SP slices or SI macroblocks

This process is invoked when decoding P macroblock types in an SP slice type or an SI macroblock type in SI slices.

Inputs to this process are the prediction residual transform coefficient levels and the predicted samples for the current macroblock.

Outputs of this process are the decoded samples of the current macroblock prior to the deblocking filter process.

This subclause specifies the transform coefficient decoding process and picture construction process for P macroblock types in SP slices and SI macroblock type in SI slices.

NOTE – SP slices make use of Inter predictive coding to exploit temporal redundancy in the sequence, in a similar manner to P slice coding. Unlike P slice coding, however, SP slice coding allows identical reconstruction of a slice even when different reference pictures are being used. SI slices make use of spatial prediction, in a similar manner to I slices. SI slice coding allows identical reconstruction to a corresponding SP slice. The properties of SP and SI slices aid in providing functionalities for bitstream switching, splicing, random access, fast-forward, fast reverse, and error resilience/recovery.

An SP slice consists of macroblocks coded either as I macroblock types or P macroblock types.

An SI slice consists of macroblocks coded either as I macroblock types or SI macroblock type.

The transform coefficient decoding process and picture construction process prior to deblocking filter process for I macroblock types in SI slices is invoked as specified in subclause 8.5. SI macroblock type is decoded as described below.

When the current macroblock is coded as P_Skip, all values of LumaLevel, ChromaDCLevel, ChromaACLevel are set equal to 0 for the current macroblock.

8.6.1 SP decoding process for non-switching pictures

This process is invoked, when decoding P macroblock types in SP slices in which `sp_for_switch_flag` is equal to 0.

Inputs to this process are Inter prediction samples for the current macroblock from subclause 8.4 and the prediction residual transform coefficient levels.

Outputs of this process are the decoded samples of the current macroblock prior to the deblocking filter process.

This subclause applies to all macroblocks in SP slices in which `sp_for_switch_flag` is equal to 0, except those with macroblock prediction mode equal to `Intra_4x4` or `Intra_16x16`. It does not apply to SI slices.

8.6.1.1 Luma transform coefficient decoding process

Inputs to this process are Inter prediction luma samples for the current macroblock $pred_L$ from subclause 8.4 and the prediction residual transform coefficient levels, LumaLevel, and the index of the 4x4 luma block `luma4x4BlkIdx`.

The position of the upper-left sample of the 4x4 luma block with index `luma4x4BlkIdx` inside the current macroblock is derived by invoking the inverse 4x4 luma block scanning process in subclause 6.4.3 with `luma4x4BlkIdx` as the input and the output being assigned to (x, y) .

Let the variable p be a 4x4 array of prediction samples with element p_{ij} being derived as follows.

$$p_{ij} = pred_L[x + j, y + i] \quad \text{with } i, j = 0..3 \quad (8-422)$$

The variable p is transformed producing transform coefficients c^p according to:

$$c^p = \begin{bmatrix} 1 & 1 & 1 & 1 \\ 2 & 1 & -1 & -2 \\ 1 & -1 & -1 & 1 \\ 1 & -2 & 2 & -1 \end{bmatrix} \begin{bmatrix} p_{00} & p_{01} & p_{02} & p_{03} \\ p_{10} & p_{11} & p_{12} & p_{13} \\ p_{20} & p_{21} & p_{22} & p_{23} \\ p_{30} & p_{31} & p_{32} & p_{33} \end{bmatrix} \begin{bmatrix} 1 & 2 & 1 & 1 \\ 1 & 1 & -1 & -2 \\ 1 & -1 & -1 & 2 \\ 1 & -2 & 1 & -1 \end{bmatrix} \quad (8-423)$$

The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with `LumaLevel[luma4x4BlkIdx]` as the input and the two-dimensional array c^t with elements c_{ij}^t as the output.

The prediction residual transform coefficients c^r are scaled using quantisation parameter QP_Y , and added to the transform coefficients of the prediction block c^p with $i, j = 0..3$ as follows.

$$c_{ij}^s = c_{ij}^p + ((c_{ij}^r * \text{LevelScale}(QP_Y \% 6, i, j) * A_{ij}) \ll (QP_Y / 6)) \gg 10) \quad (8-424)$$

where $\text{LevelScale}(m, i, j)$ is specified in Equation 8-312, and where A_{ij} is specified as:

$$A_{ij} = \begin{cases} 16 & \text{for } (i, j) \in \{(0,0), (0,2), (2,0), (2,2)\}, \\ 25 & \text{for } (i, j) \in \{(1,1), (1,3), (3,1), (3,3)\}, \\ 20 & \text{otherwise;} \end{cases} \quad (8-425)$$

The function $\text{LevelScale2}(m, i, j)$, used in the formulas below, is specified as:

$$\text{LevelScale2}(m, i, j) = \begin{cases} w_{m0} & \text{for } (i, j) \in \{(0,0), (0,2), (2,0), (2,2)\}, \\ w_{m1} & \text{for } (i, j) \in \{(1,1), (1,3), (3,1), (3,3)\}, \\ w_{m2} & \text{otherwise;} \end{cases} \quad (8-426)$$

where the first and second subscripts of w are row and column indices, respectively, of the matrix specified as:

$$w = \begin{bmatrix} 13107 & 5243 & 8066 \\ 11916 & 4660 & 7490 \\ 10082 & 4194 & 6554 \\ 9362 & 3647 & 5825 \\ 8192 & 3355 & 5243 \\ 7282 & 2893 & 4559 \end{bmatrix} \quad (8-427)$$

The resulting sum, c^s , is quantised with a quantisation parameter QS_Y and with $i, j = 0..3$ as follows.

$$c_{ij} = \text{Sign}(c_{ij}^s) * ((\text{Abs}(c_{ij}^s) * \text{LevelScale2}(QS_Y \% 6, i, j) + (1 \ll (14 + QS_Y / 6))) \gg (15 + QS_Y / 6)) \quad (8-428)$$

The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with c as the input and r as the output.

The 4x4 array u with elements u_{ij} is derived as follows.

$$u_{ij} = \text{Clip1}_Y(r_{ij}) \text{ with } i, j = 0..3 \quad (8-429)$$

The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with luma4x4BlkIdx and u as the inputs.

8.6.1.2 Chroma transform coefficient decoding process

Inputs to this process are Inter prediction chroma samples for the current macroblock from subclause 8.4 and the prediction residual transform coefficient levels, ChromaDCLevel and ChromaACLevel .

This process is invoked twice: once for the Cb component and once for the Cr component. The component is referred to by replacing C with Cb for the Cb component and C with Cr for the Cr component. Let $iCbCr$ select the current chroma component.

For each 4x4 block of the current chroma component indexed using chroma4x4BlkIdx with chroma4x4BlkIdx equal to 0..3, the following applies.

- The position of the upper-left sample of a 4x4 chroma block with index chroma4x4BlkIdx inside the macroblock is derived as follows.

$$x = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 0) \quad (8-430)$$

$$y = \text{InverseRasterScan}(\text{chroma4x4BlkIdx}, 4, 4, 8, 1) \quad (8-431)$$

- Let p be a 4x4 array of prediction samples with elements p_{ij} being derived as follows.

$$p_{ij} = \text{pred}_c[x + j, y + i] \quad \text{with } i, j = 0..3 \quad (8-432)$$

- The 4x4 array p is transformed producing transform coefficients $c^p(\text{chroma4x4BlkIdx})$ using Equation 8-423.
- The variable chromaList , which is a list of 16 entries, is derived. $\text{chromaList}[0]$ is set equal to 0. $\text{chromaList}[k]$ with index $k = 1..15$ are specified as follows.

$$\text{chromaList}[k] = \text{ChromaACLevel}[\text{iCbCr}][\text{chroma4x4BlkIdx}][k - 1] \quad (8-433)$$

- The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with chromaList as the input and the 4x4 array c^r as the output.
- The prediction residual transform coefficients c^r are scaled using quantisation parameter QP_C , and added to the transform coefficients of the prediction block c^p with $i, j = 0..3$ except for the combination $i = 0, j = 0$ as follows.

$$c_{ij}^s = c_{ij}^p(\text{chroma4x4BlkIdx}) + (((c_{ij}^r * \text{LevelScale}(QP_C \% 6, i, j) * A_{ij}) \ll (QP_C / 6)) \gg 10) \quad (8-434)$$

- The resulting sum, c^s , is quantised with a quantisation parameter QS_C and with $i, j = 0..3$ except for the combination $i = 0, j = 0$ as follows. The derivation of $c_{00}(\text{chroma4x4BlkIdx})$ is described below in this subclause.

$$c_{ij}(\text{chroma4x4BlkIdx}) = (\text{Sign}(c_{ij}^s) * (\text{Abs}(c_{ij}^s) * \text{LevelScale2}(QS_C \% 6, i, j) + (1 \ll (14 + QS_C / 6)))) \gg (15 + QS_C / 6) \quad (8-435)$$

- The scaling and transformation process for residual 4x4 blocks as specified in 8.5.10 is invoked with $c(\text{chroma4x4BlkIdx})$ as the input and r as the output.
- The 4x4 array u with elements u_{ij} is derived as follows.

$$u_{ij} = \text{Clip1}_c(r_{ij}) \quad \text{with } i, j = 0..3 \quad (8-436)$$

- The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with chroma4x4BlkIdx and u as the inputs.

The derivation of the DC transform coefficient level $c_{00}(\text{chroma4x4BlkIdx})$ is specified as follows. The DC transform coefficients of the 4 prediction chroma 4x4 blocks of the current component of the macroblock are assembled into a 2x2 matrix with elements $c_{00}^p(\text{chroma4x4BlkIdx})$ and a 2x2 transform is applied to the DC transform coefficients as follows

$$dc^p = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} c_{00}^p(0) & c_{00}^p(1) \\ c_{00}^p(2) & c_{00}^p(3) \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \quad (8-437)$$

The chroma DC prediction residual transform coefficient levels, $\text{ChromaDCLevel}[\text{iCbCr}][k]$ with $k = 0..3$ are scaled using quantisation parameter QP , and added to the prediction DC transform coefficients as follows.

$$dc_{ij}^s = dc_{ij}^p + (((\text{ChromaDCLevel}[\text{iCbCr}][j * 2 + i] * \text{LevelScale}(QP_C \% 6, 0, 0) * A_{00}) \ll (QP_C / 6)) \gg 9) \quad \text{with } i, j = 0, 1 \quad (8-438)$$

The 2x2 array dc^s , is quantised using the quantisation parameter QS_C as follows.

$$dc_{ij}^r = (\text{Sign}(dc_{ij}^s) * (\text{Abs}(dc_{ij}^s) * \text{LevelScale2}(QS_C \% 6, 0, 0) + (1 \ll (15 + QS_C / 6)))) \gg (16 + QS_C / 6) \quad \text{with } i, j = 0, 1 \quad (8-439)$$

The 2x2 array f with elements f_{ij} and $i, j = 0..1$ is derived as follows.

$$f = \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} dc_{00}^r & dc_{01}^r \\ dc_{10}^r & dc_{11}^r \end{bmatrix} \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix}. \quad (8-440)$$

Scaling of the elements f_{ij} of f is performed as follows.

$$c_{00}(j * 2 + i) = ((f_{ij} * \text{LevelScale}(QS_C \% 6, 0, 0)) \ll (QS_C / 6)) \gg 5 \text{ with } i, j = 0, 1 \quad (8-441)$$

8.6.2 SP and SI slice decoding process for switching pictures

This process is invoked, when decoding P macroblock types in SP slices in which `sp_for_switch_flag` is equal to 1 and when decoding SI macroblock type in SI slices.

Inputs to this process are the prediction residual transform coefficient levels and the prediction sample arrays pred_L , pred_{Cb} and pred_{Cr} for the current macroblock.

8.6.2.1 Luma transform coefficient decoding process

Inputs to this process are prediction luma samples pred_L and the luma prediction residual transform coefficient levels, `LumaLevel`.

The 4x4 array p with elements p_{ij} with $i, j = 0..3$ is derived as in subclause 8.6.1.1, is transformed according to Equation 8-423 to produce transform coefficients c^p . These transform coefficients are then quantised with the quantisation parameter QS_Y , as follows:

$$c_{ij}^s = \text{Sign}(c_{ij}^p) * ((\text{Abs}(c_{ij}^p) * \text{LevelScale2}(QS_Y \% 6, i, j) + (1 \ll (14 + QS_Y / 6))) \gg (15 + QS_Y / 6)) \quad \text{with } i, j = 0..3 \quad (8-442)$$

The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with `LumaLevel[luma4x4BlkIdx]` as the input and the two-dimensional array c^r with elements c_{ij}^r as the output.

The 4x4 array c with elements c_{ij} with $i, j = 0..3$ is derived as follows.

$$c_{ij} = c_{ij}^r + c_{ij}^s \text{ with } i, j = 0..3 \quad (8-443)$$

The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with c as the input and r as the output.

The 4x4 array u with elements u_{ij} is derived as follows.

$$u_{ij} = \text{Clip1}_Y(r_{ij}) \text{ with } i, j = 0..3 \quad (8-444)$$

The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with `luma4x4BlkIdx` and u as the inputs.

8.6.2.2 Chroma transform coefficient decoding process

Inputs to this process are predicted chroma samples for the current macroblock from subclause 8.4 and the prediction residual transform coefficient levels, `ChromaDCLevel` and `ChromaACLevel`.

This process is invoked twice: once for the Cb component and once for the Cr component. The component is referred to by replacing C with Cb for the Cb component and C with Cr for the Cr component. Let `iCbCr` select the current chroma component.

For each 4x4 block of the current chroma component indexed using `chroma4x4BlkIdx` with `chroma4x4BlkIdx` equal to 0..3, the following applies.

1. The 4x4 array p with elements p_{ij} with $i, j = 0..3$ is derived as in subclause 8.6.1.2, is transformed according to Equation 8-423 to produce transform coefficients $c^p(\text{chroma4x4BlkIdx})$. These transform coefficients are then quantised with the quantisation parameter QS_C , with $i, j = 0..3$ except for the combination $i = 0, j = 0$ as follows. The processing of $c_{00}^p(\text{chroma4x4BlkIdx})$ is described below in this subclause.

$$c_{ij}^s = (\text{Sign}(c_{ij}^p(\text{chroma4x4BlkIdx})) * (\text{Abs}(c_{ij}^p(\text{chroma4x4BlkIdx})) * \text{LevelScale2}(\text{QSC} \% 6, i, j) + (1 \ll (14 + \text{QSC} / 6)))) \gg (15 + \text{QSC} / 6) \quad (8-445)$$

- The variable chromaList, which is a list of 16 entries, is derived. chromaList[0] is set equal to 0. chromaList[k] with index k = 1..15 are specified as follows.

$$\text{chromaList}[k] = \text{ChromaACLevel}[\text{iCbCr}][\text{chroma4x4BlkIdx}][k - 1] \quad (8-446)$$

- The inverse transform coefficient scanning process as described in subclause 8.5.5 is invoked with chromaList as the input and the two-dimensional array $c^r(\text{chroma4x4BlkIdx})$ with elements $c_{ij}^r(\text{chroma4x4BlkIdx})$ as the output.
- The 4x4 array $c(\text{chroma4x4BlkIdx})$ with elements $c_{ij}(\text{chroma4x4BlkIdx})$ with $i, j = 0..3$ except for the combination $i = 0, j = 0$ is derived as follows. The derivation of $c_{00}(\text{chroma4x4BlkIdx})$ is described below.

$$c_{ij}(\text{chroma4x4BlkIdx}) = c_{ij}^r(\text{chroma4x4BlkIdx}) + c_{ij}^s \quad (8-447)$$

- The scaling and transformation process for residual 4x4 blocks as specified in subclause 8.5.10 is invoked with $c(\text{chroma4x4BlkIdx})$ as the input and r as the output.
- The 4x4 array u with elements u_{ij} is derived as follows.

$$u_{ij} = \text{Clip1}_c(r_{ij}) \text{ with } i, j = 0..3 \quad (8-448)$$

- The picture construction process prior to deblocking filter process in subclause 8.5.12 is invoked with chroma4x4BlkIdx and u as the inputs.

The derivation of the DC transform coefficient level $c_{00}(\text{chroma4x4BlkIdx})$ is specified as follows. The DC transform coefficients of the 4 prediction 4x4 chroma blocks of the current component of the macroblock, $c_{00}^p(\text{chroma4x4BlkIdx})$, are assembled into a 2x2 matrix, and a 2x2 transform is applied to the DC transform coefficients of these blocks according to Equation 8-437 resulting in DC transform coefficients dc_{ij}^p .

These DC transform coefficients are then quantised with the quantisation parameter QSC , as given by:

$$dc_{ij}^s = (\text{Sign}(dc_{ij}^p) * (\text{Abs}(dc_{ij}^p) * \text{LevelScale2}(\text{QSC} \% 6, 0, 0) + (1 \ll (15 + \text{QSC} / 6)))) \gg (16 + \text{QSC} / 6) \quad \text{with } i, j = 0, 1 \quad (8-449)$$

The parsed chroma DC prediction residual transform coefficients, $\text{ChromaDCLevel}[\text{iCbCr}][k]$ with $k = 0..3$ are added to these quantised DC transform coefficients of the prediction block, as given by:

$$dc_{ij}^r = dc_{ij}^s + \text{ChromaDCLevel}[\text{iCbCr}][j * 2 + i] \quad \text{with } i, j = 0, 1 \quad (8-450)$$

The 2x2 array f with elements f_{ij} and $i, j = 0..1$ is derived using Equation 8-440.

The 2x2 array f with elements f_{ij} and $i, j = 0..1$ is copied as follows.

$$c_{00}(j * 2 + i) = f_{ij} \quad \text{with } i, j = 0, 1 \quad (8-451)$$

8.7 Deblocking filter process

A conditional filtering process is applied to all NxN (where $N = 4$ or $N = 8$ for luma, and $N = 4$ for chroma) block edges of a picture, except edges at the boundary of the picture and any edges for which the deblocking filter process is disabled by `disable_deblocking_filter_idc`, as specified below. This filtering process is performed on a macroblock basis after the completion of the picture construction process prior to deblocking filter process (as specified in subclauses 8.5 and 8.6) for the entire decoded picture, with all macroblocks in a picture processed in order of increasing macroblock addresses.

NOTE 1 – Prior to the operation of the deblocking filter process for each macroblock, the deblocked samples of the macroblock or macroblock pair above (if any) and the macroblock or macroblock pair to the left (if any) of the current macroblock are always available because the deblocking filter process is performed after the completion of the picture construction process prior to deblocking filter process for the entire decoded picture. However, for purposes of determining which edges are to be filtered

when `disable_deblocking_filter_idc` is equal to 2, macroblocks in different slices are considered not available during specified steps of the operation of the deblocking filter process.

The deblocking filter process is invoked for the luma and chroma components separately. For each macroblock and each component, vertical edges are filtered first, starting with the edge on the left-hand side of the macroblock proceeding through the edges towards the right-hand side of the macroblock in their geometrical order, and then horizontal edges are filtered, starting with the edge on the top of the macroblock proceeding through the edges towards the bottom of the macroblock in their geometrical order. Figure 8-10 shows edges of a macroblock which can be interpreted as luma or chroma edges.

When interpreting the edges in Figure 8-10 as luma edges, depending on the `transform_size_8x8_flag`, the following applies.

- If `transform_size_8x8_flag` is equal to 0, both types, the solid bold and dashed bold luma edges are filtered.
- Otherwise (`transform_size_8x8_flag` is equal to 1), only the solid bold luma edges are filtered.

When interpreting the edges in Figure 8-10 as chroma edges, depending on `chroma_format_idc`, the following applies.

- If `chroma_format_idc` is equal to 1 (4:2:0 format), only the solid bold chroma edges are filtered.
- Otherwise, if `chroma_format_idc` is equal to 2 (4:2:2 format), the solid bold vertical chroma edges are filtered and both types, the solid bold and dashed bold horizontal chroma edges are filtered.
- Otherwise, if `chroma_format_idc` is equal to 3 (4:4:4 format), both types, the solid bold and dashed bold chroma edges are filtered.
- Otherwise (`chroma_format_idc` is equal to 0 (monochrome)), no chroma edges are filtered.

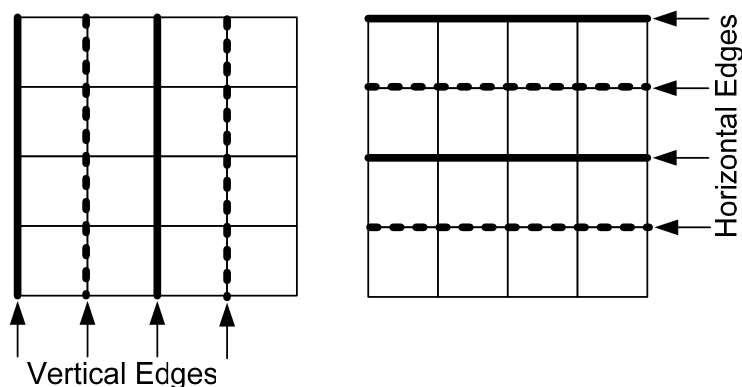


Figure 8-10 – Boundaries in a macroblock to be filtered

For the current macroblock address `CurrMbAddr` proceeding over values $0..PicSizeInMbs - 1$, the following applies.

1. The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to `mbAddrA` and `mbAddrB`.
2. The variables `fieldModeMbFlag`, `filterInternalEdgesFlag`, `filterLeftMbEdgeFlag` and `filterTopMbEdgeFlag` are derived as follows.
 - The variable `fieldModeMbFlag` is derived as follows.
 - If any of the following conditions is true, `fieldModeMbFlag` is set equal to 1.
 - `field_pic_flag` is equal to 1
 - `MbaffFrameFlag` is equal to 1 and the macroblock `CurrMbAddr` is a field macroblock
 - Otherwise, `fieldModeMbFlag` is set equal to 0.
 - The variable `filterInternalEdgesFlag` is derived as follows.

- If `disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is equal to 1, the variable `filterInternalEdgesFlag` is set equal to 0;
 - Otherwise (`disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is not equal to 1), the variable `filterInternalEdgesFlag` is set equal to 1.
 - The variable `filterLeftMbEdgeFlag` is derived as follows.
 - If any of the following conditions is true, the variable `filterLeftMbEdgeFlag` is set equal to 0.
 - `MbaffFrameFlag` is equal to 0 and `CurrMbAddr % PicWidthInMbs` is equal to 0.
 - `MbaffFrameFlag` is equal to 1 and $(CurrMbAddr \gg 1) \% PicWidthInMbs$ is equal to 0
 - `disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is equal to 1
 - `disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is equal to 2 and the macroblock `mbAddrA` is not available
 - Otherwise, the variable `filterLeftMbEdgeFlag` is set equal to 1.
 - The variable `filterTopMbEdgeFlag` is derived as follows.
 - If any of the following conditions is true, the variable `filterTopMbEdgeFlag` is set equal to 0.
 - `MbaffFrameFlag` is equal to 0 and `CurrMbAddr` is less than `PicWidthInMbs`.
 - `MbaffFrameFlag` is equal to 1, $(CurrMbAddr \gg 1)$ is less than `PicWidthInMbs`, and the macroblock `CurrMbAddr` is a field macroblock.
 - `MbaffFrameFlag` is equal to 1, $(CurrMbAddr \gg 1)$ is less than `PicWidthInMbs`, the macroblock `CurrMbAddr` is a frame macroblock, and `CurrMbAddr % 2` is equal to 0.
 - `disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is equal to 1
 - `disable_deblocking_filter_idc` for the slice that contains the macroblock `CurrMbAddr` is equal to 2 and the macroblock `mbAddrB` is not available
 - Otherwise, the variable `filterTopMbEdgeFlag` is set equal to 1.
3. Given the variables `fieldModeMbFlag`, `filterInternalEdgesFlag`, `filterLeftMbEdgeFlag` and `filterTopMbEdgeFlag` the deblocking filtering is controlled as follows.
- When `filterLeftMbEdgeFlag` is equal to 1, the filtering of the left vertical luma edge is specified as follows.
 - The process specified in subclause 8.7.1 is invoked with `chromaEdgeFlag` = 0, `verticalEdgeFlag` = 1, `fieldModeFilteringFlag` = `fieldModeMbFlag`, and $(xE_k, yE_k) = (0, k)$ with $k = 0..15$ as input and S'_L as output.
 - When `filterInternalEdgesFlag` is equal to 1, the filtering of the internal vertical luma edges is specified as follows.
 - When `transform_size_8x8_flag` is equal to 0, the process specified in subclause 8.7.1 is invoked with `chromaEdgeFlag` = 0, `verticalEdgeFlag` = 1, `fieldModeFilteringFlag` = `fieldModeMbFlag`, and $(xE_k, yE_k) = (4, k)$ with $k = 0..15$ as input and S'_L as output.
 - The process specified in subclause 8.7.1 is invoked with `chromaEdgeFlag` = 0, `verticalEdgeFlag` = 1, `fieldModeFilteringFlag` = `fieldModeMbFlag`, and $(xE_k, yE_k) = (8, k)$ with $k = 0..15$ as input and S'_L as output.
 - When `transform_size_8x8_flag` is equal to 0, the process specified in subclause 8.7.1 is invoked with `chromaEdgeFlag` = 0, `verticalEdgeFlag` = 1, `fieldModeFilteringFlag` = `fieldModeMbFlag`, and $(xE_k, yE_k) = (12, k)$ with $k = 0..15$ as input and S'_L as output.
 - When `filterTopMbEdgeFlag` is equal to 1, the filtering of the top horizontal luma edge is specified as follows.
 - If `MbaffFrameFlag` is equal to 1, $(CurrMbAddr \% 2)$ is equal to 0, `CurrMbAddr` is greater than or equal to $2 * PicWidthInMbs$, the macroblock `CurrMbAddr` is a frame macroblock, and the macroblock $(CurrMbAddr - 2 * PicWidthInMbs + 1)$ is a field macroblock, the following applies.
 - The process specified in subclause 8.7.1 is invoked with `chromaEdgeFlag` = 0, `verticalEdgeFlag` = 0, `fieldModeFilteringFlag` = 1, and $(xE_k, yE_k) = (k, 0)$ with $k = 0..15$ as input and S'_L as output.

- The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 0$, $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = 1$, and $(x_{E_k}, y_{E_k}) = (k, 1)$ with $k = 0..15$ as input and S'_L as output.
- Otherwise, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 0$, $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 0)$ with $k = 0..15$ as input and S'_L as output.
- When $\text{filterInternalEdgesFlag}$ is equal to 1, the filtering of the internal horizontal luma edges is specified as follows.
 - When $\text{transform_size_8x8_flag}$ is equal to 0, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 0$, $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 4)$ with $k = 0..15$ as input and S'_L as output.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 0$, $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 8)$ with $k = 0..15$ as input and S'_L as output.
 - When $\text{transform_size_8x8_flag}$ is equal to 0, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 0$, $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 12)$ with $k = 0..15$ as input and S'_L as output.
- For the filtering of both chroma components with $\text{iCbCr} = 0$ for Cb and $\text{iCbCr} = 1$ for Cr, the following applies.
 - When $\text{filterLeftMbEdgeFlag}$ is equal to 1, the filtering of the left vertical chroma edge is specified as follows.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 1$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (0, k)$ with $k = 0..MbHeightC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - When $\text{filterInternalEdgesFlag}$ is equal to 1, the filtering of the internal vertical chroma edge is specified as follows.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 1$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (4, k)$ with $k = 0..MbHeightC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - When chroma_format_idc is equal to 3, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 1$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (8, k)$ with $k = 0..MbHeightC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - When chroma_format_idc is equal to 3, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 1$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (12, k)$ with $k = 0..MbHeightC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
- When $\text{filterTopMbEdgeFlag}$ is equal to 1, the filtering of the top horizontal chroma edge is specified as follows.
 - If MbaffFrameFlag is equal to 1, $(\text{CurrMbAddr} \% 2)$ is equal to 0, CurrMbAddr is greater than or equal to $2 * \text{PicWidthInMbs}$, the macroblock CurrMbAddr is a frame macroblock, and the macroblock $(\text{CurrMbAddr} - 2 * \text{PicWidthInMbs} + 1)$ is a field macroblock, the following applies.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = 1$, and $(x_{E_k}, y_{E_k}) = (k, 0)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = 1$, and $(x_{E_k}, y_{E_k}) = (k, 1)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.

- Otherwise, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 0)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
- When $\text{filterInternalEdgesFlag}$ is equal to 1, the filtering of the internal horizontal chroma edge is specified as follows.
 - The process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 4)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - When chroma_format_idc is not equal to 1, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 8)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.
 - When chroma_format_idc is not equal to 1, the process specified in subclause 8.7.1 is invoked with $\text{chromaEdgeFlag} = 1$, iCbCr , $\text{verticalEdgeFlag} = 0$, $\text{fieldModeFilteringFlag} = \text{fieldModeMbFlag}$, and $(x_{E_k}, y_{E_k}) = (k, 12)$ with $k = 0..MbWidthC - 1$ as input and S'_C with C being replaced by Cb for $\text{iCbCr} = 0$ and C being replaced by Cr for $\text{iCbCr} = 1$ as output.

NOTE 2 – When field mode filtering ($\text{fieldModeFilteringFlag}$ is equal to 1) is applied across the top horizontal edges of a frame macroblock, this vertical filtering across the top or bottom macroblock boundary may involve some samples that extend across an internal block edge that is also filtered internally in frame mode.

NOTE 3 – For example, in 4:2:0 chroma format when $\text{transform_size_8x8_flag}$ is equal to 0, the following applies. 3 horizontal luma edges, 1 horizontal chroma edge for Cb , and 1 horizontal chroma edge for Cr are filtered that are internal to a macroblock. When field mode filtering ($\text{fieldModeFilteringFlag}$ is equal to 1) is applied to the top edges of a frame macroblock, 2 horizontal luma, 2 horizontal chroma edges for Cb , and 2 horizontal chroma edges for Cr between the frame macroblock and the above macroblock pair are filtered using field mode filtering, for a total of up to 5 horizontal luma edges, 3 horizontal chroma edges for Cb , and 3 horizontal chroma edges for Cr filtered that are considered to be controlled by the frame macroblock. In all other cases, at most 4 horizontal luma, 2 horizontal chroma edges for Cb , and 2 horizontal chroma edges for Cr are filtered that are considered to be controlled by a particular macroblock.

Finally, 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.

8.7.1 Filtering process for block edges

Inputs to this process are chromaEdgeFlag , the chroma component index iCbCr (when chromaEdgeFlag is equal to 1), verticalEdgeFlag , $\text{fieldModeFilteringFlag}$, and a set of nE sample locations (x_{E_k}, y_{E_k}) , with $k = 0..nE - 1$, expressed relative to the upper left corner of the macroblock CurrMbAddr . The set of sample locations (x_{E_k}, y_{E_k}) represent the sample locations immediately to the right of a vertical edge (when verticalEdgeFlag is equal to 1) or immediately below a horizontal edge (when verticalEdgeFlag is equal to 0).

The variable nE is derived as follows.

- If chromaEdgeFlag is equal to 0, nE is set equal to 16.
- Otherwise (chromaEdgeFlag is equal to 1), nE is set equal to $(\text{verticalEdgeFlag} == 1) ? MbHeightC : MbWidthC$.

Let s' be a variable specifying a luma or chroma sample array, be derived as follows.

- If chromaEdgeFlag is equal to 0, s' represents the luma sample array S'_L of the current picture.
- Otherwise, if chromaEdgeFlag is equal to 1 and iCbCr is equal to 0, s' represents the chroma sample array S'_{Cb} of the chroma component Cb of the current picture.
- Otherwise (chromaEdgeFlag is equal to 1 and iCbCr is equal to 1), s' represents the chroma sample array S'_{Cr} of the chroma component Cr of the current picture.

The variable dy is derived as follows.

- If $\text{fieldModeFilteringFlag}$ is equal to 1 and MbaffFrameFlag is equal to 1, dy is set equal to 2.
- Otherwise ($\text{fieldModeFilteringFlag}$ is equal to 0 or MbaffFrameFlag is equal to 0), dy is set equal to 1.

The position of the upper-left luma sample of the macroblock CurrMbAddr is derived by invoking the inverse macroblock scanning process in subclause 6.4.1 with mbAddr = CurrMbAddr as input and the output being assigned to (xI, yI).

The variables xP and yP are derived as follows.

- If chromaEdgeFlag is equal to 0, xP is set equal to xI and yP is set equal to yI.
- Otherwise (chromaEdgeFlag is equal to 1), xP is set equal to xI / SubWidthC and yP is set equal to (yI + SubHeightC – 1) / SubHeightC.

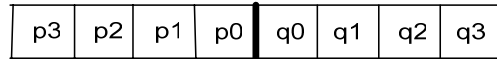


Figure 8-11 – Convention for describing samples across a 4x4 block horizontal or vertical boundary

For each sample location (xE_k, yE_k), k = 0 .. nE - 1, the following applies.

- The filtering process is applied to a set of eight samples across a 4x4 block horizontal or vertical edge denoted as p_i and q_i with i = 0..3 as shown in Figure 8-11 with the edge lying between p₀ and q₀. p_i and q_i with i = 0..3 are specified as follows.

- If verticalEdgeFlag is equal to 1,

$$q_i = s'[xP + xE_k + i, yP + dy * yE_k] \quad (8-452)$$

$$p_i = s'[xP + xE_k - i - 1, yP + dy * yE_k] \quad (8-453)$$

- Otherwise (verticalEdgeFlag is equal to 0),

$$q_i = s'[xP + xE_k, yP + dy * (yE_k + i) - (yE_k \% 2)] \quad (8-454)$$

$$p_i = s'[xP + xE_k, yP + dy * (yE_k - i - 1) - (yE_k \% 2)] \quad (8-455)$$

- The process specified in subclause 8.7.2 is invoked with the sample values p_i and q_i (i = 0..3), chromaEdgeFlag, verticalEdgeFlag, and fieldModeFilteringFlag as input, and the output is assigned to the filtered result sample values p'_i and q'_i with i = 0..2.
- The input sample values p_i and q_i with i = 0..2 are replaced by the corresponding filtered result sample values p'_i and q'_i with i = 0..2 inside the sample array s' as follows.

- If verticalEdgeFlag is equal to 1,

$$s'[xP + xE_k + i, yP + dy * yE_k] = q'_i \quad (8-456)$$

$$s'[xP + xE_k - i - 1, yP + dy * yE_k] = p'_i \quad (8-457)$$

- Otherwise (verticalEdgeFlag is equal to 0),

$$s'[xP + xE_k, yP + dy * (yE_k + i) - (yE_k \% 2)] = q'_i \quad (8-458)$$

$$s'[xP + xE_k, yP + dy * (yE_k - i - 1) - (yE_k \% 2)] = p'_i \quad (8-459)$$

8.7.2 Filtering process for a set of samples across a horizontal or vertical block edge

Inputs to this process are the input sample values p_i and q_i with i in the range of 0..3 of a single set of samples across an edge that is to be filtered, `chromaEdgeFlag`, `verticalEdgeFlag`, and `fieldModeFilteringFlag`.

Outputs of this process are the filtered result sample values p'_i and q'_i with i in the range of 0..2.

The content dependent boundary filtering strength variable `bS` is derived as follows.

- If `chromaEdgeFlag` is equal to 0, the derivation process for the content dependent boundary filtering strength specified in subclause 8.7.2.1 is invoked with p_0 , q_0 , and `verticalEdgeFlag` as input, and the output is assigned to `bS`.
- Otherwise (`chromaEdgeFlag` is equal to 1), the `bS` used for filtering a set of samples of a horizontal or vertical chroma edge is set equal to the value of `bS` for filtering the set of samples of a horizontal or vertical luma edge, respectively, that contains the luma sample at location (`SubWidthC * x`, `SubHeightC * y`) inside the luma array of the same field, where (x , y) is the location of the chroma sample q_0 inside the chroma array for that field.

The process specified in subclause 8.7.2.2 is invoked with p_0 , q_0 , p_1 , q_1 , `chromaEdgeFlag`, and `bS` as input, and the output is assigned to `filterSamplesFlag`, `indexA`, α , and β .

Depending on the variable `filterSamplesFlag`, the following applies.

- If `filterSamplesFlag` is equal to 1, the following applies.
 - If `bS` is less than 4, the process specified in subclause 8.7.2.3 is invoked with p_i and q_i ($i = 0..2$), `chromaEdgeFlag`, `bS`, β , and `indexA` given as input, and the output is assigned to p'_i and q'_i ($i = 0..2$).
 - Otherwise (`bS` is equal to 4), the process specified in subclause 8.7.2.4 is invoked with p_i and q_i ($i = 0..3$), `chromaEdgeFlag`, α , and β given as input, and the output is assigned to p'_i and q'_i ($i = 0..2$).
- Otherwise (`filterSamplesFlag` is equal to 0), the filtered result samples p'_i and q'_i ($i = 0..2$) are replaced by the corresponding input samples p_i and q_i :

$$\text{for } i = 0..2, \quad p'_i = p_i \quad (8-460)$$

$$\text{for } i = 0..2, \quad q'_i = q_i \quad (8-461)$$

8.7.2.1 Derivation process for the luma content dependent boundary filtering strength

Inputs to this process are the input sample values p_0 and q_0 of a single set of samples across an edge that is to be filtered and `verticalEdgeFlag`.

Output of this process is the variable `bS`.

Let the variable `mixedModeEdgeFlag` be derived as follows.

- If `MbaffFrameFlag` is equal to 1 and the samples p_0 and q_0 are in different macroblock pairs, one of which is a field macroblock pair and the other is a frame macroblock pair, `mixedModeEdgeFlag` is set equal to 1
- Otherwise, `mixedModeEdgeFlag` is set equal to 0.

The variable `bS` is derived as follows.

- If the block edge is also a macroblock edge and any of the following conditions are true, a value of `bS` equal to 4 is the output:
 - the samples p_0 and q_0 are both in frame macroblocks and either or both of the samples p_0 or q_0 is in a macroblock coded using an Intra macroblock prediction mode
 - the samples p_0 and q_0 are both in frame macroblocks and either or both of the samples p_0 or q_0 is in a macroblock that is in a slice with `slice_type` equal to SP or SI
 - `MbaffFrameFlag` is equal to 1 or `field_pic_flag` is equal to 1, and `verticalEdgeFlag` is equal to 1, and either or both of the samples p_0 or q_0 is in a macroblock coded using an Intra macroblock prediction mode
 - `MbaffFrameFlag` is equal to 1 or `field_pic_flag` is equal to 1, and `verticalEdgeFlag` is equal to 1, and either or both of the samples p_0 or q_0 is in a macroblock that is in a slice with `slice_type` equal to SP or SI

- Otherwise, if any of the following conditions are true, a value of bS equal to 3 is the output:
 - mixedModeEdgeFlag is equal to 0 and either or both of the samples p_0 or q_0 is in a macroblock coded using an Intra macroblock prediction mode
 - mixedModeEdgeFlag is equal to 0 and either or both of the samples p_0 or q_0 is in a macroblock that is in a slice with slice_type equal to SP or SI
 - mixedModeEdgeFlag is equal to 1, verticalEdgeFlag is equal to 0, and either or both of the samples p_0 or q_0 is in a macroblock coded using an Intra macroblock prediction mode
 - mixedModeEdgeFlag is equal to 1, verticalEdgeFlag is equal to 0, and either or both of the samples p_0 or q_0 is in a macroblock that is in a slice with slice_type equal to SP or SI
- Otherwise, if the following condition is true, a value of bS equal to 2 is the output:
 - the luma block containing sample p_0 or the luma block containing sample q_0 contains non-zero transform coefficient levels
- Otherwise, if any of the following conditions are true, a value of bS equal to 1 is the output:
 - mixedModeEdgeFlag is equal to 1
 - mixedModeEdgeFlag is equal to 0 and for the prediction of the macroblock/sub-macroblock partition containing the sample p_0 different reference pictures or a different number of motion vectors are used than for the prediction of the macroblock/sub-macroblock partition containing the sample q_0 .

NOTE 1 – The determination of whether the reference pictures used for the two macroblock/sub-macroblock partitions 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 or not the index position within a reference picture list is different or not.
 - mixedModeEdgeFlag is equal to 0 and one motion vector is used to predict the macroblock/sub-macroblock partition containing the sample p_0 and one motion vector is used to predict the macroblock/sub-macroblock partition 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 frame samples.
 - mixedModeEdgeFlag is equal to 0 and two motion vectors and two different reference pictures are used to predict the macroblock/sub-macroblock partition containing the sample p_0 and two motion vectors for the same two reference pictures are used to predict the macroblock/sub-macroblock partition 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 macroblock/sub-macroblock partitions for the same reference picture is greater than or equal to 4 in units of quarter luma frame samples.
 - mixedModeEdgeFlag is equal to 0 and two motion vectors for the same reference picture are used to predict the macroblock/sub-macroblock partition containing the sample p_0 and two motion vectors for the same reference picture are used to predict the macroblock/sub-macroblock partition 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 macroblock/sub-macroblock partitions is greater than or equal to 4 in quarter luma frame samples or the absolute difference between the horizontal or vertical component of the list 1 motion vectors used in the prediction of the two macroblock/sub-macroblock partitions is greater than or equal to 4 in units of quarter luma frame samples.
 - The absolute difference between the horizontal or vertical component of list 0 motion vector used in the prediction of the macroblock/sub-macroblock partition containing the sample p_0 and the list 1 motion vector used in the prediction of the macroblock/sub-macroblock partition containing the sample q_0 is greater than or equal to 4 in units of quarter luma frame samples or the absolute difference between the horizontal or vertical component of the list 1 motion vector used in the prediction of the macroblock/sub-macroblock partition containing the sample p_0 and list 0 motion vector used in the prediction of the macroblock/sub-macroblock partition containing the sample q_0 is greater than or equal to 4 in units of quarter luma frame samples.

NOTE 2 – A vertical difference of 4 in units of quarter luma frame samples is a difference of 2 in units of quarter luma field samples

- Otherwise, a value of bS equal to 0 is the output.

8.7.2.2 Derivation process for the thresholds for each block edge

Inputs to this process are the input sample values p_0 , q_0 , p_1 and q_1 of a single set of samples across an edge that is to be filtered, chromaEdgeFlag, and bS, for the set of input samples, as specified in 8.7.2.

Outputs of this process are the variable filterSamplesFlag, which indicates whether the input samples are filtered, the value of indexA, and the values of the threshold variables α and β .

Let qP_p and qP_q be variables specifying quantisation parameter values for the macroblocks containing the samples p_0 and q_0 , respectively. The variables qP_z (with z being replaced by p or q) are derived as follows.

- If chromaEdgeFlag is equal to 0, the following applies.
 - If the macroblock containing the sample z_0 is an I_PCM macroblock, qP_z is set to 0.
 - Otherwise (the macroblock containing the sample z_0 is not an I_PCM macroblock), qP_z is set to the value of QP_Y of the macroblock containing the sample z_0 .
- Otherwise (chromaEdgeFlag is equal to 1), the following applies.
 - If the macroblock containing the sample z_0 is an I_PCM macroblock, qP_z is set to the value of QP_C that corresponds to a value of 0 for QP_Y as specified in subclause 8.5.7.
 - Otherwise (the macroblock containing the sample z_0 is not an I_PCM macroblock), qP_z is set to the value of QP_C that corresponds to the value QP_Y of the macroblock containing the sample z_0 as specified in subclause 8.5.7.

Let qP_{av} be a variable specifying an average quantisation parameter. It is derived as follows.

$$qP_{av} = (qP_p + qP_q + 1) \gg 1 \quad (8-462)$$

NOTE – In SP and SI slices, qP_{av} is derived in the same way as in other slice types. QS_Y from Equation 7-28 is not used in the deblocking filter.

Let indexA be a variable that is used to access the α table (Table 8-16) as well as the t_{C0} table (Table 8-17), which is used in filtering of edges with bS less than 4 as specified in subclause 8.7.2.3, and let indexB be a variable that is used to access the β table (Table 8-16). The variables indexA and indexB are derived as follows, where the values of FilterOffsetA and FilterOffsetB are the values of those variables specified in subclause 7.4.3 for the slice that contains the macroblock containing sample q_0 .

$$\text{indexA} = \text{Clip3}(0, 51, qP_{av} + \text{FilterOffsetA}) \quad (8-463)$$

$$\text{indexB} = \text{Clip3}(0, 51, qP_{av} + \text{FilterOffsetB}) \quad (8-464)$$

The variables α' and β' depending on the values of indexA and indexB are specified in Table 8-16. Depending on chromaEdgeFlag, the corresponding threshold variables α and β are derived as follows.

- If chromaEdgeFlag is equal to 0,

$$\alpha = \alpha' * (1 \ll (\text{BitDepth}_Y - 8)) \quad (8-465)$$

$$\beta = \beta' * (1 \ll (\text{BitDepth}_Y - 8)) \quad (8-466)$$

- Otherwise (chromaEdgeFlag is equal to 1),

$$\alpha = \alpha' * (1 \ll (\text{BitDepth}_C - 8)) \quad (8-467)$$

$$\beta = \beta' * (1 \ll (\text{BitDepth}_C - 8)) \quad (8-468)$$

The variable filterSamplesFlag is derived by

$$\text{filterSamplesFlag} = (\text{bS} \neq 0 \ \&\& \ \text{Abs}(p_0 - q_0) < \alpha \ \&\& \ \text{Abs}(p_1 - p_0) < \beta \ \&\& \ \text{Abs}(q_1 - q_0) < \beta) \quad (8-469)$$

Table 8-16 – Derivation of offset dependent threshold variables α' and β' from indexA and indexB

		indexA (for α') or indexB (for β')																									
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
α'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	4	5	6	7	8	9	10	12	13	
β'	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	3	3	3	3	4	4	4	

Table 8-16 (concluded) – Derivation of indexA and indexB from offset dependent threshold variables α' and β'

		indexA (for α') or indexB (for β')																													
		26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51				
α'	15	17	20	22	25	28	32	36	40	45	50	56	63	71	80	90	101	113	127	144	162	182	203	226	255	255					
β'	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	16	17	17	18	18					

8.7.2.3 Filtering process for edges with bS less than 4

Inputs to this process are the input sample values p_i and q_i ($i = 0..2$) of a single set of samples across an edge that is to be filtered, chromaEdgeFlag, bS, β , and indexA, for the set of input samples, as specified in 8.7.2.

Outputs of this process are the filtered result sample values p'_i and q'_i ($i = 0..2$) for the set of input sample values.

The filtered result samples p'_0 and q'_0 are derived by

$$\Delta = \text{Clip3}(-t_c, t_c, ((((q_0 - p_0) \ll 2) + (p_1 - q_1) + 4) \gg 3)) \quad (8-470)$$

$$p'_0 = \text{Clip1}(p_0 + \Delta) \quad (8-471)$$

$$q'_0 = \text{Clip1}(q_0 - \Delta) \quad (8-472)$$

where the threshold t_c is determined as follows.

- If chromaEdgeFlag is equal to 0,

$$t_c = t_{c0} + ((a_p < \beta) ? 1 : 0) + ((a_q < \beta) ? 1 : 0) \quad (8-473)$$

- Otherwise (chromaEdgeFlag is equal to 1),

$$t_c = t_{c0} + 1 \quad (8-474)$$

Depending on the values of indexA and bS the variable t'_{c0} is specified in Table 8-17. Depending on chromaEdgeFlag, the corresponding threshold variable t_{c0} is derived as follows.

- If chromaEdgeFlag is equal to 0,

$$t_{c0} = t'_{c0} * (1 \ll (\text{BitDepth}_Y - 8)) \quad (8-475)$$

- Otherwise (chromaEdgeFlag is equal to 1),

$$t_{c0} = t'_{c0} * (1 \ll (\text{BitDepth}_C - 8)) \quad (8-476)$$

Let a_p and a_q be two threshold variables specified by

$$a_p = \text{Abs}(p_2 - p_0) \quad (8-477)$$

$$a_q = \text{Abs}(q_2 - q_0) \quad (8-478)$$

The filtered result sample p'_1 is derived as follows

- If chromaEdgeFlag is equal to 0 and a_p is less than β ,

$$p'_1 = p_1 + \text{Clip3}(-t_{c0}, t_{c0}, (p_2 + ((p_0 + q_0 + 1) \gg 1) - (p_1 \ll 1)) \gg 1) \quad (8-479)$$

- Otherwise (chromaEdgeFlag is equal to 1 or a_p is greater than or equal to β),

$$p'_1 = p_1 \quad (8-480)$$

The filtered result sample q'_1 is derived as follows

- If chromaEdgeFlag is equal to 0 and a_q is less than β ,

$$q'_1 = q_1 + \text{Clip3}(-t_{c0}, t_{c0}, (q_2 + ((p_0 + q_0 + 1) \gg 1) - (q_1 \ll 1)) \gg 1) \quad (8-481)$$

- Otherwise (chromaEdgeFlag is equal to 1 or a_q is greater than or equal to β),

$$q'_1 = q_1 \quad (8-482)$$

The filtered result samples p'_2 and q'_2 are always set equal to the input samples p_2 and q_2 :

$$p'_2 = p_2 \quad (8-483)$$

$$q'_2 = q_2 \quad (8-484)$$

Table 8-17 – Value of variable t'_{c0} as a function of indexA and bS

	indexA																									
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
bS = 1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
bS = 2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1
bS = 3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1

Table 8-17 (concluded) – Value of variable t'_{c0} as a function of indexA and bS

	indexA																									
	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51
bS = 1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	4	4	4	5	6	6	7	8	9	10	11	13
bS = 2	1	1	1	1	1	2	2	2	2	3	3	3	4	4	5	5	6	7	8	8	10	11	12	13	15	17
bS = 3	1	2	2	2	2	3	3	3	4	4	4	5	6	6	7	8	9	10	11	13	14	16	18	20	23	25

8.7.2.4 Filtering process for edges for bS equal to 4

Inputs to this process are the input sample values p_i and q_i ($i = 0..3$) of a single set of samples across an edge that is to be filtered, the variable `chromaEdgeFlag`, and the values of the threshold variables α and β for the set of samples, as specified in subclause 8.7.2.

Outputs of this process are the filtered result sample values p'_i and q'_i ($i = 0..2$) for the set of input sample values.

Let a_p and a_q be two threshold variables as specified in Equations 8-477 and 8-478, respectively, in subclause 8.7.2.3.

The filtered result samples p'_i ($i = 0..2$) are derived as follows.

- If `chromaEdgeFlag` is equal to 0 and the following condition holds,

$$a_p < \beta \ \&\& \ \text{Abs}(p_0 - q_0) < ((\alpha \gg 2) + 2) \quad (8-485)$$

then the variables p'_0 , p'_1 , and p'_2 are derived by

$$p'_0 = (p_2 + 2*p_1 + 2*p_0 + 2*q_0 + q_1 + 4) \gg 3 \quad (8-486)$$

$$p'_1 = (p_2 + p_1 + p_0 + q_0 + 2) \gg 2 \quad (8-487)$$

$$p'_2 = (2*p_3 + 3*p_2 + p_1 + p_0 + q_0 + 4) \gg 3 \quad (8-488)$$

- Otherwise (`chromaEdgeFlag` is equal to 1 or the condition in Equation 8-485 does not hold), the variables p'_0 , p'_1 , and p'_2 are derived by

$$p'_0 = (2*p_1 + p_0 + q_1 + 2) \gg 2 \quad (8-489)$$

$$p'_1 = p_1 \quad (8-490)$$

$$p'_2 = p_2 \quad (8-491)$$

The filtered result samples q'_i ($i = 0..2$) are derived as follows.

- If `chromaEdgeFlag` is equal to 0 and the following condition holds,

$$a_q < \beta \ \&\& \ \text{Abs}(p_0 - q_0) < ((\alpha \gg 2) + 2) \quad (8-492)$$

then the variables q'_0 , q'_1 , and q'_2 are derived by

$$q'_0 = (p_1 + 2*p_0 + 2*q_0 + 2*q_1 + q_2 + 4) \gg 3 \quad (8-493)$$

$$q'_1 = (p_0 + q_0 + q_1 + q_2 + 2) \gg 2 \quad (8-494)$$

$$q'_2 = (2*q_3 + 3*q_2 + q_1 + q_0 + p_0 + 4) \gg 3 \quad (8-495)$$

- Otherwise (`chromaEdgeFlag` is equal to 1 or the condition in Equation 8-492 does not hold), the variables q'_0 , q'_1 , and q'_2 are derived by

$$q'_0 = (2*q_1 + q_0 + p_1 + 2) \gg 2 \quad (8-496)$$

$$q'_1 = q_1 \quad (8-497)$$

$$q'_2 = q_2 \quad (8-498)$$

9 Parsing process

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), me(v), se(v), te(v) (see subclause 9.1), ce(v) (see subclause 9.2), or ae(v) (see subclause 9.3).

9.1 Parsing process for Exp-Golomb codes

This process is invoked when the descriptor of a syntax element in the syntax tables in subclause 7.3 is equal to ue(v), me(v), se(v), or te(v). For syntax elements in subclauses 7.3.4 and 7.3.5, this process is invoked only when entropy_coding_mode_flag is equal to 0.

Inputs to this process are bits from the RBSP.

Outputs of this process are syntax element values.

Syntax elements coded as ue(v), me(v), or se(v) are Exp-Golomb-coded. Syntax elements coded as te(v) are truncated 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++ )
    b = read_bits( 1 )

```

The variable codeNum is then assigned as follows:

$$\text{codeNum} = 2^{\text{leadingZeroBits}} - 1 + \text{read_bits}(\text{leadingZeroBits})$$

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 in the above pseudo-code 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 being in the range 0 to leadingZeroBits - 1, inclusive. Each x_i can take on values 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, if 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 9.1.1 with codeNum as the input.
- Otherwise, if the syntax element is coded as me(v), the value of the syntax element is derived by invoking the mapping process for coded block pattern as specified in subclause 9.1.2 with codeNum as the input.
- Otherwise (the syntax element is coded as te(v)), the range of possible values for the syntax element is determined first. The range of this syntax element may be between 0 and x, with x being greater than or equal to 1 and the range is used in the derivation of the value of the syntax element value as follows
 - If x is greater than 1, codeNum and the value of the syntax element is derived in the same way as for syntax elements coded as ue(v)
 - Otherwise (x is equal to 1), the parsing process for codeNum which is equal to the value of the syntax element is given by a process equivalent to:

```
b = read_bits( 1 )
codeNum = !b
```

9.1.1 Mapping process for signed Exp-Golomb codes

Input to this process is codeNum as specified in subclause 9.1.

Output of this process is a value of a syntax element coded as se(v).

The syntax element is assigned to the codeNum by ordering the syntax element by its absolute value in increasing order and representing the positive value for a given absolute value with the lower codeNum. Table 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	$(-1)^{k+1} \text{Ceil}(k \div 2)$

9.1.2 Mapping process for coded block pattern

Input to this process is codeNum as specified in subclause 9.1.

Output of this process is a value of the syntax element coded_block_pattern coded as me(v).

Table 9-4 shows the assignment of coded_block_pattern to codeNum depending on whether the macroblock prediction mode is equal to Intra_4x4, Intra_8x8 or Inter.

Table 9-4 – Assignment of codeNum to values of coded_block_pattern for macroblock prediction modes

(a) chroma_format_idc is not equal to 0

codeNum	coded_block_pattern	
	Intra_4x4, Intra_8x8	Inter
0	47	0
1	31	16
2	15	1
3	0	2
4	23	4
5	27	8
6	29	32
7	30	3
8	7	5
9	11	10
10	13	12
11	14	15
12	39	47
13	43	7
14	45	11

codeNum	coded_block_pattern	
	Intra_4x4, Intra_8x8	Inter
15	46	13
16	16	14
17	3	6
18	5	9
19	10	31
20	12	35
21	19	37
22	21	42
23	26	44
24	28	33
25	35	34
26	37	36
27	42	40
28	44	39
29	1	43
30	2	45
31	4	46
32	8	17
33	17	18
34	18	20
35	20	24
36	24	19
37	6	21
38	9	26
39	22	28
40	25	23
41	32	27
42	33	29
43	34	30
44	36	22
45	40	25
46	38	38
47	41	41

(b) chroma_format_idc is equal to 0

codeNum	coded_block_pattern	
	Intra_4x4, Intra_8x8	Inter
0	15	0
1	0	1
2	7	2
3	11	4
4	13	8
5	14	3
6	3	5
7	5	10
8	10	12
9	12	15
10	1	7
11	2	11
12	4	13
13	8	14
14	6	6
15	9	9

9.2 CAVLC parsing process for transform coefficient levels

This process is invoked when parsing syntax elements with descriptor equal to $ce(v)$ in subclause 7.3.5.3.1 and when `entropy_coding_mode_flag` is equal to 0.

Inputs to this process are bits from slice data, a maximum number of non-zero transform coefficient levels `maxNumCoeff`, the luma block index `luma4x4BlkIdx` or the chroma block index `chroma4x4BlkIdx` of the current block of transform coefficient levels.

Output of this process is the list `coeffLevel` containing transform coefficient levels of the luma block with block index `luma4x4BlkIdx` or the chroma block with block index `chroma4x4BlkIdx`.

The process is specified in the following ordered steps:

1. All transform coefficient levels, with indices from 0 to `maxNumCoeff - 1`, in the list `coeffLevel` are set equal to 0.
2. The total number of non-zero transform coefficient levels `TotalCoeff(coeff_token)` and the number of trailing one transform coefficient levels `TrailingOnes(coeff_token)` are derived by parsing `coeff_token` (see subclause 9.2.1) as follows.
 - If the number of non-zero transform coefficient levels `TotalCoeff(coeff_token)` is equal to 0, the list `coeffLevel` containing 0 values is returned and no further step is carried out.
 - Otherwise, the following steps are carried out.
 - a. The non-zero transform coefficient levels are derived by parsing `trailing_ones_sign_flag`, `level_prefix`, and `level_suffix` (see subclause 9.2.2).
 - b. The runs of zero transform coefficient levels before each non-zero transform coefficient level are derived by parsing `total_zeros` and `run_before` (see subclause 9.2.3).

- c. The level and run information are combined into the list `coeffLevel` (see subclause 9.2.4).

9.2.1 Parsing process for total number of transform coefficient levels and trailing ones

Inputs to this process are bits from slice data, a maximum number of non-zero transform coefficient levels `maxNumCoeff`, the luma block index `luma4x4BlkIdx` or the chroma block index `chroma4x4BlkIdx` of the current block of transform.

Outputs of this process are `TotalCoeff(coeff_token)` and `TrailingOnes(coeff_token)`.

The syntax element `coeff_token` is decoded using one of the six VLCs specified in the six right-most columns of Table 9-5. Each VLC specifies both `TotalCoeff(coeff_token)` and `TrailingOnes(coeff_token)` for a given codeword `coeff_token`. VLC selection is dependent upon a variable `nC` that is derived as follows.

- If the CAVLC parsing process is invoked for `ChromaDCLevel`, `nC` is derived as follows.
 - If `chroma_format_idc` is equal to 1, `nC` is set equal to -1,
 - Otherwise, if `chroma_format_idc` is equal to 2, `nC` is set equal to -2,
 - Otherwise (`chroma_format_idc` is equal to 3), `nC` is set equal to 0.
- Otherwise, the following applies.
 - When the CAVLC parsing process is invoked for `Intra16x16DCLevel`, `luma4x4BlkIdx` is set equal to 0.
 - The variables `blkA` and `blkB` are derived as follows.
 - If the CAVLC parsing process is invoked for `Intra16x16DCLevel`, `Intra16x16ACLevel`, or `LumaLevel`, the process specified in subclause 6.4.8.3 is invoked with `luma4x4BlkIdx` as the input, and the output is assigned to `mbAddrA`, `mbAddrB`, `luma4x4BlkIdxA`, and `luma4x4BlkIdxB`. The 4x4 luma block specified by `mbAddrA\luma4x4BlkIdxA` is assigned to `blkA`, and the 4x4 luma block specified by `mbAddrB\luma4x4BlkIdxB` is assigned to `blkB`.
 - Otherwise (the CAVLC parsing process is invoked for `ChromaACLevel`), the process specified in subclause 6.4.8.4 is invoked with `chroma4x4BlkIdx` as input, and the output is assigned to `mbAddrA`, `mbAddrB`, `chroma4x4BlkIdxA`, and `chroma4x4BlkIdxB`. The 4x4 chroma block specified by `mbAddrA\CbCr\chroma4x4BlkIdxA` is assigned to `blkA`, and the 4x4 chroma block specified by `mbAddrB\CbCr\chroma4x4BlkIdxB` is assigned to `blkB`.
 - Let `nA` and `nB` be the number of non-zero transform coefficient levels (given by `TotalCoeff(coeff_token)`) in the block of transform coefficient levels `blkA` located to the left of the current block and the block of transform coefficient levels `blkB` located above the current block, respectively.
 - With `N` replaced by `A` and `B`, in `mbAddrN`, `blkN`, and `nN` the following applies.
 - If any of the following conditions is true, `nN` is set equal to 0.
 - `mbAddrN` is not available
 - The current macroblock is coded using an Intra prediction mode, `constrained_intra_pred_flag` is equal to 1 and `mbAddrN` is coded using Inter prediction and slice data partitioning is in use (`nal_unit_type` is in the range of 2 to 4, inclusive).
 - The macroblock `mbAddrN` has `mb_type` equal to `P_Skip` or `B_Skip`
 - All AC residual transform coefficient levels of the neighbouring block `blkN` are equal to 0 due to the corresponding bit of `CodedBlockPatternLuma` or `CodedBlockPatternChroma` being equal to 0
 - Otherwise, if `mbAddrN` is an `I_PCM` macroblock, `nN` is set equal to 16.
 - Otherwise, `nN` is set equal to the value `TotalCoeff(coeff_token)` of the neighbouring block `blkN`.

NOTE 1 – The values `nA` and `nB` that are derived using `TotalCoeff(coeff_token)` do not include the DC transform coefficient levels in `Intra_16x16` macroblocks or DC transform coefficient levels in chroma blocks, because these transform coefficient levels are decoded separately. When the block above or to the left belongs to an `Intra_16x16` macroblock, or is a chroma block, `nA` and `nB` is the number of decoded non-zero AC transform coefficient levels.

NOTE 2 – When parsing for `Intra16x16DCLevel`, the values `nA` and `nB` are based on the number of non-zero transform coefficient levels in adjacent 4x4 blocks and not on the number of non-zero DC transform coefficient levels in adjacent 16x16 blocks.
- Given the values of `nA` and `nB`, the variable `nC` is derived as follows.

- If both mbAddrA and mbAddrB are available, the variable nC is set equal to $(nA + nB + 1) \gg 1$.
- Otherwise (mbAddrA is not available or mbAddrB is not available), the variable nC is set equal to $nA + nB$.

The value of TotalCoeff(coeff_token) resulting from decoding coeff_token shall be in the range of 0 to maxNumCoeff, inclusive.

Table 9-5 – coeff_token mapping to TotalCoeff(coeff_token) and TrailingOnes(coeff_token)

TrailingOnes (coeff_token)	TotalCoeff (coeff_token)	$0 \leq nC < 2$	$2 \leq nC < 4$	$4 \leq nC < 8$	$8 \leq nC$	$nC == -1$	$nC == -2$
0	0	1	11	1111	0000 11	01	1
0	1	0001 01	0010 11	0011 11	0000 00	0001 11	0001 111
1	1	01	10	1110	0000 01	1	01
0	2	0000 0111	0001 11	0010 11	0001 00	0001 00	0001 110
1	2	0001 00	0011 1	0111 1	0001 01	0001 10	0001 101
2	2	001	011	1101	0001 10	001	001
0	3	0000 0011 1	0000 111	0010 00	0010 00	0000 11	0000 0011 1
1	3	0000 0110	0010 10	0110 0	0010 01	0000 011	0001 100
2	3	0000 101	0010 01	0111 0	0010 10	0000 010	0001 011
3	3	0001 1	0101	1100	0010 11	0001 01	0000 1
0	4	0000 0001 11	0000 0111	0001 111	0011 00	0000 10	0000 0011 0
1	4	0000 0011 0	0001 10	0101 0	0011 01	0000 0011	0000 0010 1
2	4	0000 0101	0001 01	0101 1	0011 10	0000 0010	0001 010
3	4	0000 11	0100	1011	0011 11	0000 000	0000 01
0	5	0000 0000 111	0000 0100	0001 011	0100 00	-	0000 0001 11
1	5	0000 0001 10	0000 110	0100 0	0100 01	-	0000 0001 10
2	5	0000 0010 1	0000 101	0100 1	0100 10	-	0000 0010 0
3	5	0000 100	0011 0	1010	0100 11	-	0001 001
0	6	0000 0000 0111 1	0000 0011 1	0001 001	0101 00	-	0000 0000 111
1	6	0000 0000 110	0000 0110	0011 10	0101 01	-	0000 0000 110
2	6	0000 0001 01	0000 0101	0011 01	0101 10	-	0000 0001 01
3	6	0000 0100	0010 00	1001	0101 11	-	0001 000
0	7	0000 0000 0101 1	0000 0001 111	0001 000	0110 00	-	0000 0000 0111
1	7	0000 0000 0111 0	0000 0011 0	0010 10	0110 01	-	0000 0000 0110
2	7	0000 0000 101	0000 0010 1	0010 01	0110 10	-	0000 0000 101
3	7	0000 0010 0	0001 00	1000	0110 11	-	0000 0001 00
0	8	0000 0000 0100 0	0000 0001 011	0000 1111	0111 00	-	0000 0000 0011 1
1	8	0000 0000 0101 0	0000 0001 110	0001 110	0111 01	-	0000 0000 0101
2	8	0000 0000 0110 1	0000 0001 101	0001 101	0111 10	-	0000 0000 0100
3	8	0000 0001 00	0000 100	0110 1	0111 11	-	0000 0000 100
0	9	0000 0000 0011 11	0000 0000 1111	0000 1011	1000 00	-	

TrailingOnes (coeff_token)	TotalCoeff (coeff_token)	$0 \leq nC < 2$	$2 \leq nC < 4$	$4 \leq nC < 8$	$8 \leq nC$	$nC == -1$	$nC == -2$
1	9	0000 0000 0011 10	0000 0001 010	0000 1110	1000 01	-	
2	9	0000 0000 0100 1	0000 0001 001	0001 010	1000 10	-	
3	9	0000 0000 100	0000 0010 0	0011 00	1000 11	-	
0	10	0000 0000 0010 11	0000 0000 1011	0000 0111 1	1001 00	-	
1	10	0000 0000 0010 10	0000 0000 1110	0000 1010	1001 01	-	
2	10	0000 0000 0011 01	0000 0000 1101	0000 1101	1001 10	-	
3	10	0000 0000 0110 0	0000 0001 100	0001 100	1001 11	-	
0	11	0000 0000 0001 111	0000 0000 1000	0000 0101 1	1010 00	-	
1	11	0000 0000 0001 110	0000 0000 1010	0000 0111 0	1010 01	-	
2	11	0000 0000 0010 01	0000 0000 1001	0000 1001	1010 10	-	
3	11	0000 0000 0011 00	0000 0001 000	0000 1100	1010 11	-	
0	12	0000 0000 0001 011	0000 0000 0111 1	0000 0100 0	1011 00	-	
1	12	0000 0000 0001 010	0000 0000 0111 0	0000 0101 0	1011 01	-	
2	12	0000 0000 0001 101	0000 0000 0110 1	0000 0110 1	1011 10	-	
3	12	0000 0000 0010 00	0000 0000 1100	0000 1000	1011 11	-	
0	13	0000 0000 0000 1111	0000 0000 0101 1	0000 0011 01	1100 00	-	
1	13	0000 0000 0000 001	0000 0000 0101 0	0000 0011 1	1100 01	-	
2	13	0000 0000 0001 001	0000 0000 0100 1	0000 0100 1	1100 10	-	
3	13	0000 0000 0001 100	0000 0000 0110 0	0000 0110 0	1100 11	-	
0	14	0000 0000 0000 1011	0000 0000 0011 1	0000 0010 01	1101 00	-	
1	14	0000 0000 0000 1110	0000 0000 0010 11	0000 0011 00	1101 01	-	
2	14	0000 0000 0000 1101	0000 0000 0011 0	0000 0010 11	1101 10	-	
3	14	0000 0000 0001 000	0000 0000 0100 0	0000 0010 10	1101 11	-	
0	15	0000 0000 0000 0111	0000 0000 0010 01	0000 0001 01	1110 00	-	
1	15	0000 0000 0000 1010	0000 0000 0010 00	0000 0010 00	1110 01	-	
2	15	0000 0000 0000 1001	0000 0000 0010 10	0000 0001 11	1110 10	-	
3	15	0000 0000 0000 1100	0000 0000 0000 1	0000 0001 10	1110 11	-	
0	16	0000 0000 0000 0100	0000 0000 0001 11	0000 0000 01	1111 00	-	
1	16	0000 0000 0000 0110	0000 0000 0001 10	0000 0001 00	1111 01	-	
2	16	0000 0000 0000 0101	0000 0000 0001 01	0000 0000 11	1111 10	-	
3	16	0000 0000 0000 1000	0000 0000 0001 00	0000 0000 10	1111 11	-	

9.2.2 Parsing process for level information

Inputs to this process are bits from slice data, the number of non-zero transform coefficient levels TotalCoeff(coeff_token), and the number of trailing one transform coefficient levels TrailingOnes(coeff_token).

Output of this process is a list with name level containing transform coefficient levels.

Initially an index i is set equal to 0. Then the following procedure is iteratively applied $\text{TrailingOnes}(\text{coeff_token})$ times to decode the trailing one transform coefficient levels (if any):

- A 1-bit syntax element $\text{trailing_ones_sign_flag}$ is decoded and evaluated as follows.
 - If $\text{trailing_ones_sign_flag}$ is equal to 0, the value +1 is assigned to $\text{level}[i]$.
 - Otherwise ($\text{trailing_ones_sign_flag}$ is equal to 1), the value -1 is assigned to $\text{level}[i]$.
- The index i is incremented by 1.

Following the decoding of the trailing one transform coefficient levels, a variable suffixLength is initialised as follows.

- If $\text{TotalCoeff}(\text{coeff_token})$ is greater than 10 and $\text{TrailingOnes}(\text{coeff_token})$ is less than 3, suffixLength is set equal to 1.
- Otherwise ($\text{TotalCoeff}(\text{coeff_token})$ is less than or equal to 10 or $\text{TrailingOnes}(\text{coeff_token})$ is equal to 3), suffixLength is set equal to 0.

The following procedure is then applied iteratively ($\text{TotalCoeff}(\text{coeff_token}) - \text{TrailingOnes}(\text{coeff_token})$) times to decode the remaining levels (if any):

- The syntax element level_prefix is decoded as specified in subclause 9.2.2.1.
- The variable levelSuffixSize is set equal to the variable suffixLength with the exception of the following two cases.
 - When level_prefix is equal to 14 and suffixLength is equal to 0, levelSuffixSize is set equal to 4.
 - When level_prefix is greater than or equal to 15, levelSuffixSize is set equal to $\text{level_prefix} - 3$.
- The syntax element level_suffix is decoded as follows.
 - If levelSuffixSize is greater than 0, the syntax element level_suffix is decoded as unsigned integer representation $u(v)$ with levelSuffixSize bits.
 - Otherwise (levelSuffixSize is equal to 0), the syntax element level_suffix is inferred to be equal to 0.
- A variable levelCode is set equal to $(\text{Min}(15, \text{level_prefix}) \ll \text{suffixLength}) + \text{level_suffix}$.
- When level_prefix is greater than or equal to 15 and suffixLength is equal to 0, levelCode is incremented by 15.
- When level_prefix is greater than or equal to 16, levelCode is incremented by $(1 \ll (\text{level_prefix} - 3)) - 4096$.
- When the index i is equal to $\text{TrailingOnes}(\text{coeff_token})$ and $\text{TrailingOnes}(\text{coeff_token})$ is less than 3, levelCode is incremented by 2.
- The variable $\text{level}[i]$ is derived as follows.
 - If levelCode is an even number, the value $(\text{levelCode} + 2) \gg 1$ is assigned to $\text{level}[i]$.
 - Otherwise (levelCode is an odd number), the value $(-\text{levelCode} - 1) \gg 1$ is assigned to $\text{level}[i]$.
- When suffixLength is equal to 0, suffixLength is set equal to 1.
- When the absolute value of $\text{level}[i]$ is greater than $(3 \ll (\text{suffixLength} - 1))$ and suffixLength is less than 6, suffixLength is incremented by 1.
- The index i is incremented by 1.

9.2.2.1 Parsing process for level_prefix

Inputs to this process are bits from slice data.

Output of this process is level_prefix .

The parsing process for this syntax element consists in 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++ )
    b = read_bits( 1 )
level_prefix = leadingZeroBits
```

Table 9-6 illustrates the codeword table for level_prefix.

Table 9-6 – Codeword table for level_prefix (informative)

level_prefix	bit string
0	1
1	01
2	001
3	0001
4	0000 1
5	0000 01
6	0000 001
7	0000 0001
8	0000 0000 1
9	0000 0000 01
10	0000 0000 001
11	0000 0000 0001
12	0000 0000 0000 1
13	0000 0000 0000 01
14	0000 0000 0000 001
15	0000 0000 0000 0001
...	...

9.2.3 Parsing process for run information

Inputs to this process are bits from slice data, the number of non-zero transform coefficient levels TotalCoeff(coeff_token), and the maximum number of non-zero transform coefficient levels maxNumCoeff.

Output of this process is a list of runs of zero transform coefficient levels preceding non-zero transform coefficient levels called run.

Initially, an index i is set equal to 0.

The variable zerosLeft is derived as follows.

- If the number of non-zero transform coefficient levels TotalCoeff(coeff_token) is equal to the maximum number of non-zero transform coefficient levels maxNumCoeff, a variable zerosLeft is set equal to 0.
- Otherwise (the number of non-zero transform coefficient levels TotalCoeff(coeff_token) is less than the maximum number of non-zero transform coefficient levels maxNumCoeff), total_zeros is decoded and zerosLeft is set equal to its value.

The VLC used to decode total_zeros is derived as follows:

If maxNumCoeff is equal to 4, one of the VLCs specified in Table 9-9 (a) is used.

- Otherwise, if maxNumCoeff is equal to 8, one of the VLCs specified in Table 9-9 (b) is used.
- Otherwise (maxNumCoeff is not equal to 4 and not equal to 8), VLCs from Tables 9-7 and 9-8 are used.

The following procedure is then applied iteratively (TotalCoeff(coeff_token) – 1) times:

- The variable run[i] is derived as follows.
 - If zerosLeft is greater than zero, a value run_before is decoded based on Table 9-10 and zerosLeft. run[i] is set equal to run_before.
 - Otherwise (zerosLeft is equal to 0), run[i] is set equal to 0.
- The value of run[i] is subtracted from zerosLeft and the result assigned to zerosLeft. The result of the subtraction shall be greater than or equal to 0.
- The index i is incremented by 1.

Finally the value of zerosLeft is assigned to run[i].

Table 9-7 – total_zeros tables for 4x4 blocks with TotalCoeff(coeff_token) 1 to 7

total_zeros	TotalCoeff(coeff_token)						
	1	2	3	4	5	6	7
0	1	111	0101	0001 1	0101	0000 01	0000 01
1	011	110	111	111	0100	0000 1	0000 1
2	010	101	110	0101	0011	111	101
3	0011	100	101	0100	111	110	100
4	0010	011	0100	110	110	101	011
5	0001 1	0101	0011	101	101	100	11
6	0001 0	0100	100	100	100	011	010
7	0000 11	0011	011	0011	011	010	0001
8	0000 10	0010	0010	011	0010	0001	001
9	0000 011	0001 1	0001 1	0010	0000 1	001	0000 00
10	0000 010	0001 0	0001 0	0001 0	0001	0000 00	
11	0000 0011	0000 11	0000 01	0000 1	0000 0		
12	0000 0010	0000 10	0000 1	0000 0			
13	0000 0001 1	0000 01	0000 00				
14	0000 0001 0	0000 00					
15	0000 0000 1						

Table 9-8 – total_zeros tables for 4x4 blocks with TotalCoeff(coeff_token) 8 to 15

total_zeros	TotalCoeff(coeff_token)							
	8	9	10	11	12	13	14	15
0	0000 01	0000 01	0000 1	0000	0000	000	00	0
1	0001	0000 00	0000 0	0001	0001	001	01	1
2	0000 1	0001	001	001	01	1	1	
3	011	11	11	010	1	01		
4	11	10	10	1	001			
5	10	001	01	011				
6	010	01	0001					
7	001	0000 1						
8	0000 00							

Table 9-9 – total_zeros tables for chroma DC 2x2 and 2x4 blocks

(a) Chroma DC 2x2 block (4:2:0 chroma sampling)

total_zeros	TotalCoeff(coeff_token)		
	1	2	3
0	1	1	1
1	01	01	0
2	001	00	
3	000		

(b) Chroma DC 2x4 block (4:2:2 chroma sampling)

total_zeros	TotalCoeff(coeff_token)						
	1	2	3	4	5	6	7
0	1	000	000	110	00	00	0
1	010	01	001	00	01	01	1
2	011	001	01	01	10	1	
3	0010	100	10	10	11		
4	0011	101	110	111			
5	0001	110	111				
6	0000 1	111					
7	0000 0						

Table 9-10 – Tables for run_before

run_before	zerosLeft						
	1	2	3	4	5	6	>6
0	1	1	11	11	11	11	111
1	0	01	10	10	10	000	110
2	-	00	01	01	011	001	101
3	-	-	00	001	010	011	100
4	-	-	-	000	001	010	011
5	-	-	-	-	000	101	010
6	-	-	-	-	-	100	001
7	-	-	-	-	-	-	0001
8		-	-	-	-	-	00001
9	-	-	-	-	-	-	000001
10	-	-	-	-	-	-	0000001
11	-	-	-	-	-	-	00000001
12	-	-	-	-	-	-	000000001
13	-	-	-	-	-	-	0000000001
14	-	-	-	-	-	-	00000000001

9.2.4 Combining level and run information

Input to this process are a list of transform coefficient levels called level, a list of runs called run, and the number of non-zero transform coefficient levels TotalCoeff(coeff_token).

Output of this process is an list coeffLevel of transform coefficient levels.

A variable coeffNum is set equal to -1 and an index i is set equal to (TotalCoeff(coeff_token) – 1). The following procedure is iteratively applied TotalCoeff(coeff_token) times:

- coeffNum is incremented by run[i] + 1.
- coeffLevel[coeffNum] is set equal to level[i].
- The index i is decremented by 1.

9.3 CABAC parsing process for slice data

This process is invoked when parsing syntax elements with descriptor ae(v) in subclauses 7.3.4 and 7.3.5 when entropy_coding_mode_flag is equal to 1.

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.

When starting the parsing of the slice data of a slice in subclause 7.3.4, the initialisation process of the CABAC parsing process is invoked as specified in subclause 9.3.1.

The parsing of syntax elements proceeds as follows:

For each requested value of a syntax element a binarization is derived as described in subclause 9.3.2.

The binarization for the syntax element and the sequence of parsed bins determines the decoding process flow as described in subclause 9.3.3.

For each bin of the binarization of the syntax element, which is indexed by the variable binIdx, a context index ctxIdx is derived as specified in subclause 9.3.3.1.

For each ctxIdx the arithmetic decoding process is invoked as specified in subclause 9.3.3.2.

The resulting sequence ($b_0 \dots b_{binIdx}$) of parsed bins is compared to the set of bin strings given by the binarization process after decoding of each bin. When the sequence matches a bin string in the given set, the corresponding value is assigned to the syntax element.

In case the request for a value of a syntax element is processed for the syntax element mb_type and the decoded value of mb_type is equal to I_PCM, the decoding engine is initialised after the decoding of any pcm_alignment_zero_bit and all pcm_sample_luma and pcm_sample_chroma data as specified in subclause 9.3.1.2.

The whole CABAC parsing process is illustrated in the flowchart of Figure 9-1 with the abbreviation SE for syntax element.

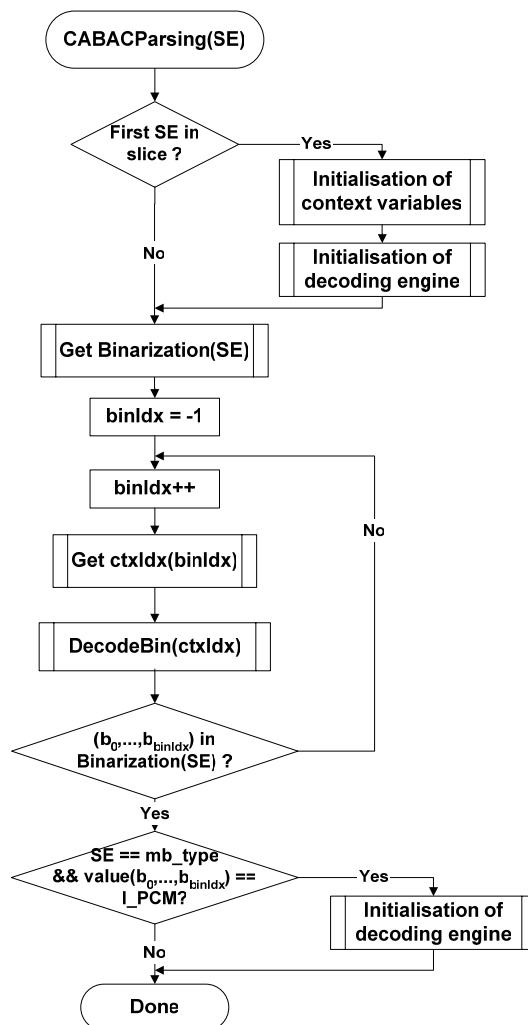


Figure 9-1 – Illustration of CABAC parsing process for a syntax element SE (informative)

9.3.1 Initialisation process

Outputs of this process are initialised CABAC internal variables.

The processes in subclauses 9.3.1.1 and 9.3.1.2 are invoked when starting the parsing of the slice data of a slice in subclause 7.3.4.

The process in subclause 9.3.1.2 is also invoked after decoding any `pcm_alignment_zero_bit` and all `pcm_sample_luma` and `pcm_sample_chroma` data for a macroblock of type I_PCM.

9.3.1.1 Initialisation process for context variables

Outputs of this process are the initialised CABAC context variables indexed by `ctxIdx`.

Table 9-12 to Table 9-23 contain the values of the variables `n` and `m` used in the initialisation of context variables that are assigned to all syntax elements in subclauses 7.3.4 and 7.3.5 except for the end-of-slice flag.

For each context variable, the two variables `pStateIdx` and `valMPS` are initialised.

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 9.3.3.2.

The two values assigned to `pStateIdx` and `valMPS` for the initialisation are derived from SliceQP_Y , which is derived in Equation 7-27. Given the two table entries (`m`, `n`),

1. `preCtxState = Clip3(1, 126, ((m * Clip3(0, 51, SliceQPY)) >> 4) + n)`
2. `if(preCtxState <= 63) {`
`pStateIdx = 63 - preCtxState`
`valMPS = 0`
`} else {`
`pStateIdx = preCtxState - 64`
`valMPS = 1`
`}`

In Table 9-11, the `ctxIdx` for which initialisation is needed for each of the slice types are listed. Also listed is the table number that includes the values of `m` and `n` needed for the initialisation. For P, SP and B slice type, the initialisation depends also on the value of the `cabac_init_idc` syntax element. Note that the syntax element names do not affect the initialisation process.

Table 9-11 – Association of `ctxIdx` and syntax elements for each slice type in the initialisation process

	Syntax element	Table	Slice type			
			SI	I	P, SP	B
slice_data()	mb_skip_flag	Table 9-13 Table 9-14			11-13	24-26
	mb_field_decoding_flag	Table 9-18	70-72	70-72	70-72	70-72
macroblock_layer()	mb_type	Table 9-12 Table 9-13 Table 9-14	0-10	3-10	14-20	27-35
	transform_size_8x8_flag	Table 9-16	na	399-401	399-401	399-401
	coded_block_pattern (luma)	Table 9-18	73-76	73-76	73-76	73-76
	coded_block_pattern (chroma)	Table 9-18	77-84	77-84	77-84	77-84
	mb_qp_delta	Table 9-17	60-63	60-63	60-63	60-63
mb_pred()	prev_intra4x4_pred_mode_flag	Table 9-17	68	68	68	68
	rem_intra4x4_pred_mode	Table 9-17	69	69	69	69
	prev_intra8x8_pred_mode_flag	Table 9-17	na	68	68	68
	rem_intra8x8_pred_mode	Table 9-17	na	69	69	69
	intra_chroma_pred_mode	Table 9-17	64-67	64-67	64-67	64-67

Table 9-11 – Association of ctxIdx and syntax elements for each slice type in the initialisation process

	Syntax element	Table	Slice type			
			SI	I	P, SP	B
mb_pred() and sub_mb_pred()	ref_idx_l0	Table 9-16			54-59	54-59
	ref_idx_l1	Table 9-16				54-59
	mvd_l0[][][0]	Table 9-15			40-46	40-46
	mvd_l1[][][0]	Table 9-15				40-46
	mvd_l0[][][1]	Table 9-15			47-53	47-53
	mvd_l1[][][1]	Table 9-15				47-53
sub_mb_pred()	sub_mb_type	Table 9-13			21-23	36-39
		Table 9-14				
residual_block_cabac()	coded_block_flag	Table 9-18	85-104	85-104	85-104	85-104
	significant_coeff_flag[]	Table 9-19	105-165	105-165	105-165	105-165
		Table 9-22	277-337	277-337	277-337	277-337
		Table 9-24	402-416	402-416	402-416	402-416
last_significant_coeff_flag[]	Table 9-24	Table 9-20	166-226	166-226	166-226	166-226
			338-398	338-398	338-398	338-398
coeff_abs_level_minus1[]	Table 9-21	Table 9-24	227-275	227-275	227-275	227-275
			426-435	426-435	426-435	426-435

NOTE 2 – ctxIdx equal to 276 is associated with the end_of_slice_flag and the bin of mb_type, which specifies the I_PCM macroblock type. The decoding process specified in subclause 9.3.3.2.4 applies to ctxIdx equal to 276. This decoding process, however, may also be implemented by using the decoding process specified in subclause 9.3.3.2.1. In this case, the initial values associated with ctxIdx equal to 276 are specified to be pStateIdx = 63 and valMPS = 0, where pStateIdx = 63 represents a non-adapting probability state.

Table 9-12 – Values of variables m and n for ctxIdx from 0 to 10

Initialisation variables	ctxIdx										
	0	1	2	3	4	5	6	7	8	9	10
m	20	2	3	20	2	3	-28	-23	-6	-1	7
n	-15	54	74	-15	54	74	127	104	53	54	51

Table 9-13 – Values of variables m and n for ctxIdx from 11 to 23

Value of cabac_init_idc	Initialisation variables	ctxIdx												
		11	12	13	14	15	16	17	18	19	20	21	22	23
0	m	23	23	21	1	0	-37	5	-13	-11	1	12	-4	17
	n	33	2	0	9	49	118	57	78	65	62	49	73	50
1	m	22	34	16	-2	4	-29	2	-6	-13	5	9	-3	10
	n	25	0	0	9	41	118	65	71	79	52	50	70	54
2	m	29	25	14	-10	-3	-27	26	-4	-24	5	6	-17	14
	n	16	0	0	51	62	99	16	85	102	57	57	73	57

Table 9-14 – Values of variables m and n for ctxIdx from 24 to 39

Value of cabac_init_idc	Initialisation variables	ctxIdx															
		24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
0	m	18	9	29	26	16	9	-46	-20	1	-13	-11	1	-6	-17	-6	9
	n	64	43	0	67	90	104	127	104	67	78	65	62	86	95	61	45
1	m	26	19	40	57	41	26	-45	-15	-4	-6	-13	5	6	-13	0	8
	n	34	22	0	2	36	69	127	101	76	71	79	52	69	90	52	43
2	m	20	20	29	54	37	12	-32	-22	-2	-4	-24	5	-6	-14	-6	4
	n	40	10	0	0	42	97	127	117	74	85	102	57	93	88	44	55

Table 9-15 – Values of variables m and n for ctxIdx from 40 to 53

Value of cabac_init_idc	Initialisation variables	ctxIdx													
		40	41	42	43	44	45	46	47	48	49	50	51	52	53
0	m	-3	-6	-11	6	7	-5	2	0	-3	-10	5	4	-3	0
	n	69	81	96	55	67	86	88	58	76	94	54	69	81	88
1	m	-2	-5	-10	2	2	-3	-3	1	-3	-6	0	-3	-7	-5
	n	69	82	96	59	75	87	100	56	74	85	59	81	86	95
2	m	-11	-15	-21	19	20	4	6	1	-5	-13	5	6	-3	-1
	n	89	103	116	57	58	84	96	63	85	106	63	75	90	101

Table 9-16 – Values of variables m and n for ctxIdx from 54 to 59, and 399 to 401

Value of cabac_init_idc	Initialisation variables	ctxIdx								
		54	55	56	57	58	59	399	400	401
I slices	m	na	na	na	na	na	na	31	31	25
	n	na	na	na	na	na	na	21	31	50
0	m	-7	-5	-4	-5	-7	1	12	11	14
	n	67	74	74	80	72	58	40	51	59
1	m	-1	-1	1	-2	-5	0	25	21	21
	n	66	77	70	86	72	61	32	49	54
2	m	3	-4	-2	-12	-7	1	21	19	17
	n	55	79	75	97	50	60	33	50	61

Table 9-17 – Values of variables m and n for ctxIdx from 60 to 69

Initialisation variables	ctxIdx									
	60	61	62	63	64	65	66	67	68	69
m	0	0	0	0	-9	4	0	-7	13	3
n	41	63	63	63	83	86	97	72	41	62

Table 9-18 – Values of variables m and n for ctxIdx from 70 to 104

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
70	0	11	0	45	13	15	7	34	88	-11	115	-13	108	-4	92	5	78
71	1	55	-4	78	7	51	-9	88	89	-12	63	-3	46	0	39	-6	55
72	0	69	-3	96	2	80	-20	127	90	-2	68	-1	65	0	65	4	61
73	-17	127	-27	126	-39	127	-36	127	91	-15	84	-1	57	-15	84	-14	83
74	-13	102	-28	98	-18	91	-17	91	92	-13	104	-9	93	-35	127	-37	127
75	0	82	-25	101	-17	96	-14	95	93	-3	70	-3	74	-2	73	-5	79
76	-7	74	-23	67	-26	81	-25	84	94	-8	93	-9	92	-12	104	-11	104
77	-21	107	-28	82	-35	98	-25	86	95	-10	90	-8	87	-9	91	-11	91
78	-27	127	-20	94	-24	102	-12	89	96	-30	127	-23	126	-31	127	-30	127
79	-31	127	-16	83	-23	97	-17	91	97	-1	74	5	54	3	55	0	65
80	-24	127	-22	110	-27	119	-31	127	98	-6	97	6	60	7	56	-2	79
81	-18	95	-21	91	-24	99	-14	76	99	-7	91	6	59	7	55	0	72
82	-27	127	-18	102	-21	110	-18	103	100	-20	127	6	69	8	61	-4	92
83	-21	114	-13	93	-18	102	-13	90	101	-4	56	-1	48	-3	53	-6	56
84	-30	127	-29	127	-36	127	-37	127	102	-5	82	0	68	0	68	3	68
85	-17	123	-7	92	0	80	11	80	103	-7	76	-4	69	-7	74	-8	71
86	-12	115	-5	89	-5	89	5	76	104	-22	125	-8	88	-9	88	-13	98
87	-16	122	-7	96	-7	94	2	84									

Table 9-19 – Values of variables m and n for ctxIdx from 105 to 165

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
105	-7	93	-2	85	-13	103	-4	86	136	-13	101	5	53	0	58	-5	75
106	-11	87	-6	78	-13	91	-12	88	137	-13	91	-2	61	-1	60	-8	80
107	-3	77	-1	75	-9	89	-5	82	138	-12	94	0	56	-3	61	-21	83
108	-5	71	-7	77	-14	92	-3	72	139	-10	88	0	56	-8	67	-21	64
109	-4	63	2	54	-8	76	-4	67	140	-16	84	-13	63	-25	84	-13	31
110	-4	68	5	50	-12	87	-8	72	141	-10	86	-5	60	-14	74	-25	64
111	-12	84	-3	68	-23	110	-16	89	142	-7	83	-1	62	-5	65	-29	94
112	-7	62	1	50	-24	105	-9	69	143	-13	87	4	57	5	52	9	75
113	-7	65	6	42	-10	78	-1	59	144	-19	94	-6	69	2	57	17	63
114	8	61	-4	81	-20	112	5	66	145	1	70	4	57	0	61	-8	74
115	5	56	1	63	-17	99	4	57	146	0	72	14	39	-9	69	-5	35
116	-2	66	-4	70	-78	127	-4	71	147	-5	74	4	51	-11	70	-2	27
117	1	64	0	67	-70	127	-2	71	148	18	59	13	68	18	55	13	91
118	0	61	2	57	-50	127	2	58	149	-8	102	3	64	-4	71	3	65
119	-2	78	-2	76	-46	127	-1	74	150	-15	100	1	61	0	58	-7	69
120	1	50	11	35	-4	66	-4	44	151	0	95	9	63	7	61	8	77
121	7	52	4	64	-5	78	-1	69	152	-4	75	7	50	9	41	-10	66
122	10	35	1	61	-4	71	0	62	153	2	72	16	39	18	25	3	62
123	0	44	11	35	-8	72	-7	51	154	-11	75	5	44	9	32	-3	68
124	11	38	18	25	2	59	-4	47	155	-3	71	4	52	5	43	-20	81
125	1	45	12	24	-1	55	-6	42	156	15	46	11	48	9	47	0	30
126	0	46	13	29	-7	70	-3	41	157	-13	69	-5	60	0	44	1	7
127	5	44	13	36	-6	75	-6	53	158	0	62	-1	59	0	51	-3	23
128	31	17	-10	93	-8	89	8	76	159	0	65	0	59	2	46	-21	74
129	1	51	-7	73	-34	119	-9	78	160	21	37	22	33	19	38	16	66
130	7	50	-2	73	-3	75	-11	83	161	-15	72	5	44	-4	66	-23	124
131	28	19	13	46	32	20	9	52	162	9	57	14	43	15	38	17	37
132	16	33	9	49	30	22	0	67	163	16	54	-1	78	12	42	44	-18
133	14	62	-7	100	-44	127	-5	90	164	0	62	0	60	9	34	50	-34
134	-13	108	9	53	0	54	1	67	165	12	72	9	69	0	89	-22	127
135	-15	100	2	53	-5	61	-15	72									

Table 9-20 – Values of variables m and n for ctxIdx from 166 to 226

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
166	24	0	11	28	4	45	4	39	197	26	-17	28	3	36	-28	28	-3
167	15	9	2	40	10	28	0	42	198	30	-25	28	4	38	-28	24	10
168	8	25	3	44	10	31	7	34	199	28	-20	32	0	38	-27	27	0
169	13	18	0	49	33	-11	11	29	200	33	-23	34	-1	34	-18	34	-14
170	15	9	0	46	52	-43	8	31	201	37	-27	30	6	35	-16	52	-44
171	13	19	2	44	18	15	6	37	202	33	-23	30	6	34	-14	39	-24
172	10	37	2	51	28	0	7	42	203	40	-28	32	9	32	-8	19	17
173	12	18	0	47	35	-22	3	40	204	38	-17	31	19	37	-6	31	25
174	6	29	4	39	38	-25	8	33	205	33	-11	26	27	35	0	36	29
175	20	33	2	62	34	0	13	43	206	40	-15	26	30	30	10	24	33
176	15	30	6	46	39	-18	13	36	207	41	-6	37	20	28	18	34	15
177	4	45	0	54	32	-12	4	47	208	38	1	28	34	26	25	30	20
178	1	58	3	54	102	-94	3	55	209	41	17	17	70	29	41	22	73
179	0	62	2	58	0	0	2	58	210	30	-6	1	67	0	75	20	34
180	7	61	4	63	56	-15	6	60	211	27	3	5	59	2	72	19	31
181	12	38	6	51	33	-4	8	44	212	26	22	9	67	8	77	27	44
182	11	45	6	57	29	10	11	44	213	37	-16	16	30	14	35	19	16
183	15	39	7	53	37	-5	14	42	214	35	-4	18	32	18	31	15	36
184	11	42	6	52	51	-29	7	48	215	38	-8	18	35	17	35	15	36
185	13	44	6	55	39	-9	4	56	216	38	-3	22	29	21	30	21	28
186	16	45	11	45	52	-34	4	52	217	37	3	24	31	17	45	25	21
187	12	41	14	36	69	-58	13	37	218	38	5	23	38	20	42	30	20
188	10	49	8	53	67	-63	9	49	219	42	0	18	43	18	45	31	12
189	30	34	-1	82	44	-5	19	58	220	35	16	20	41	27	26	27	16
190	18	42	7	55	32	7	10	48	221	39	22	11	63	16	54	24	42
191	10	55	-3	78	55	-29	12	45	222	14	48	9	59	7	66	0	93
192	17	51	15	46	32	1	0	69	223	27	37	9	64	16	56	14	56
193	17	46	22	31	0	0	20	33	224	21	60	-1	94	11	73	15	57
194	0	89	-1	84	27	36	8	63	225	12	68	-2	89	10	67	26	38
195	26	-19	25	7	33	-25	35	-18	226	2	97	-9	108	-10	116	-24	127
196	22	-17	30	-7	34	-30	33	-25									

Table 9-21 – Values of variables m and n for ctxIdx from 227 to 275

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
227	-3	71	-6	76	-23	112	-24	115	252	-12	73	-6	55	-16	72	-14	75
228	-6	42	-2	44	-15	71	-22	82	253	-8	76	0	58	-7	69	-10	79
229	-5	50	0	45	-7	61	-9	62	254	-7	80	0	64	-4	69	-9	83
230	-3	54	0	52	0	53	0	53	255	-9	88	-3	74	-5	74	-12	92
231	-2	62	-3	64	-5	66	0	59	256	-17	110	-10	90	-9	86	-18	108
232	0	58	-2	59	-11	77	-14	85	257	-11	97	0	70	2	66	-4	79
233	1	63	-4	70	-9	80	-13	89	258	-20	84	-4	29	-9	34	-22	69
234	-2	72	-4	75	-9	84	-13	94	259	-11	79	5	31	1	32	-16	75
235	-1	74	-8	82	-10	87	-11	92	260	-6	73	7	42	11	31	-2	58
236	-9	91	-17	102	-34	127	-29	127	261	-4	74	1	59	5	52	1	58
237	-5	67	-9	77	-21	101	-21	100	262	-13	86	-2	58	-2	55	-13	78
238	-5	27	3	24	-3	39	-14	57	263	-13	96	-3	72	-2	67	-9	83
239	-3	39	0	42	-5	53	-12	67	264	-11	97	-3	81	0	73	-4	81
240	-2	44	0	48	-7	61	-11	71	265	-19	117	-11	97	-8	89	-13	99
241	0	46	0	55	-11	75	-10	77	266	-8	78	0	58	3	52	-13	81
242	-16	64	-6	59	-15	77	-21	85	267	-5	33	8	5	7	4	-6	38
243	-8	68	-7	71	-17	91	-16	88	268	-4	48	10	14	10	8	-13	62
244	-10	78	-12	83	-25	107	-23	104	269	-2	53	14	18	17	8	-6	58
245	-6	77	-11	87	-25	111	-15	98	270	-3	62	13	27	16	19	-2	59
246	-10	86	-30	119	-28	122	-37	127	271	-13	71	2	40	3	37	-16	73
247	-12	92	1	58	-11	76	-10	82	272	-10	79	0	58	-1	61	-10	76
248	-15	55	-3	29	-10	44	-8	48	273	-12	86	-3	70	-5	73	-13	86
249	-10	60	-1	36	-10	52	-8	61	274	-13	90	-6	79	-1	70	-9	83
250	-6	62	1	38	-10	57	-8	66	275	-14	97	-8	85	-4	78	-10	87
251	-4	65	2	43	-9	58	-7	70									

Table 9-22 – Values of variables m and n for ctxIdx from 277 to 337

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
277	-6	93	-13	106	-21	126	-22	127	308	-16	96	-1	51	-16	77	-10	67
278	-6	84	-16	106	-23	124	-25	127	309	-7	88	7	49	-2	64	1	68
279	-8	79	-10	87	-20	110	-25	120	310	-8	85	8	52	2	61	0	77
280	0	66	-21	114	-26	126	-27	127	311	-7	85	9	41	-6	67	2	64
281	-1	71	-18	110	-25	124	-19	114	312	-9	85	6	47	-3	64	0	68
282	0	62	-14	98	-17	105	-23	117	313	-13	88	2	55	2	57	-5	78
283	-2	60	-22	110	-27	121	-25	118	314	4	66	13	41	-3	65	7	55
284	-2	59	-21	106	-27	117	-26	117	315	-3	77	10	44	-3	66	5	59
285	-5	75	-18	103	-17	102	-24	113	316	-3	76	6	50	0	62	2	65
286	-3	62	-21	107	-26	117	-28	118	317	-6	76	5	53	9	51	14	54
287	-4	58	-23	108	-27	116	-31	120	318	10	58	13	49	-1	66	15	44
288	-9	66	-26	112	-33	122	-37	124	319	-1	76	4	63	-2	71	5	60
289	-1	79	-10	96	-10	95	-10	94	320	-1	83	6	64	-2	75	2	70
290	0	71	-12	95	-14	100	-15	102	321	-7	99	-2	69	-1	70	-2	76
291	3	68	-5	91	-8	95	-10	99	322	-14	95	-2	59	-9	72	-18	86
292	10	44	-9	93	-17	111	-13	106	323	2	95	6	70	14	60	12	70
293	-7	62	-22	94	-28	114	-50	127	324	0	76	10	44	16	37	5	64
294	15	36	-5	86	-6	89	-5	92	325	-5	74	9	31	0	47	-12	70
295	14	40	9	67	-2	80	17	57	326	0	70	12	43	18	35	11	55
296	16	27	-4	80	-4	82	-5	86	327	-11	75	3	53	11	37	5	56
297	12	29	-10	85	-9	85	-13	94	328	1	68	14	34	12	41	0	69
298	1	44	-1	70	-8	81	-12	91	329	0	65	10	38	10	41	2	65
299	20	36	7	60	-1	72	-2	77	330	-14	73	-3	52	2	48	-6	74
300	18	32	9	58	5	64	0	71	331	3	62	13	40	12	41	5	54
301	5	42	5	61	1	67	-1	73	332	4	62	17	32	13	41	7	54
302	1	48	12	50	9	56	4	64	333	-1	68	7	44	0	59	-6	76
303	10	62	15	50	0	69	-7	81	334	-13	75	7	38	3	50	-11	82
304	17	46	18	49	1	69	5	64	335	11	55	13	50	19	40	-2	77
305	9	64	17	54	7	69	15	57	336	5	64	10	57	3	66	-2	77
306	-12	104	10	41	-7	69	1	67	337	12	70	26	43	18	50	25	42
307	-11	97	7	46	-6	67	0	68									

Table 9-23 – Values of variables m and n for ctxIdx from 338 to 398

ctxIdx	I and SI slices		Value of cabac_init_idc						ctxIdx	I and SI slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
338	15	6	14	11	19	-6	17	-13	369	32	-26	31	-4	40	-37	37	-17
339	6	19	11	14	18	-6	16	-9	370	37	-30	27	6	38	-30	32	1
340	7	16	9	11	14	0	17	-12	371	44	-32	34	8	46	-33	34	15
341	12	14	18	11	26	-12	27	-21	372	34	-18	30	10	42	-30	29	15
342	18	13	21	9	31	-16	37	-30	373	34	-15	24	22	40	-24	24	25
343	13	11	23	-2	33	-25	41	-40	374	40	-15	33	19	49	-29	34	22
344	13	15	32	-15	33	-22	42	-41	375	33	-7	22	32	38	-12	31	16
345	15	16	32	-15	37	-28	48	-47	376	35	-5	26	31	40	-10	35	18
346	12	23	34	-21	39	-30	39	-32	377	33	0	21	41	38	-3	31	28
347	13	23	39	-23	42	-30	46	-40	378	38	2	26	44	46	-5	33	41
348	15	20	42	-33	47	-42	52	-51	379	33	13	23	47	31	20	36	28
349	14	26	41	-31	45	-36	46	-41	380	23	35	16	65	29	30	27	47
350	14	44	46	-28	49	-34	52	-39	381	13	58	14	71	25	44	21	62
351	17	40	38	-12	41	-17	43	-19	382	29	-3	8	60	12	48	18	31
352	17	47	21	29	32	9	32	11	383	26	0	6	63	11	49	19	26
353	24	17	45	-24	69	-71	61	-55	384	22	30	17	65	26	45	36	24
354	21	21	53	-45	63	-63	56	-46	385	31	-7	21	24	22	22	24	23
355	25	22	48	-26	66	-64	62	-50	386	35	-15	23	20	23	22	27	16
356	31	27	65	-43	77	-74	81	-67	387	34	-3	26	23	27	21	24	30
357	22	29	43	-19	54	-39	45	-20	388	34	3	27	32	33	20	31	29
358	19	35	39	-10	52	-35	35	-2	389	36	-1	28	23	26	28	22	41
359	14	50	30	9	41	-10	28	15	390	34	5	28	24	30	24	22	42
360	10	57	18	26	36	0	34	1	391	32	11	23	40	27	34	16	60
361	7	63	20	27	40	-1	39	1	392	35	5	24	32	18	42	15	52
362	-2	77	0	57	30	14	30	17	393	34	12	28	29	25	39	14	60
363	-4	82	-14	82	28	26	20	38	394	39	11	23	42	18	50	3	78
364	-3	94	-5	75	23	37	18	45	395	30	29	19	57	12	70	-16	123
365	9	69	-19	97	12	55	15	54	396	34	26	22	53	21	54	21	53
366	-12	109	-35	125	11	65	0	79	397	29	39	22	61	14	71	22	56
367	36	-35	27	0	37	-33	36	-16	398	19	66	11	86	11	83	25	61
368	36	-34	28	0	39	-36	37	-14									

Table 9-24 – Values of variables m and n for ctxIdx from 402 to 459

ctxIdx	I slices		Value of cabac_init_idc						ctxIdx	I slices		Value of cabac_init_idc					
			0		1		2					0		1		2	
	m	n	m	n	m	n	m	n		m	n	m	n	m	n		
402	-17	120	-4	79	-5	85	-3	78	431	-2	55	-12	56	-9	57	-12	59
403	-20	112	-7	71	-6	81	-8	74	432	0	61	-6	60	-6	63	-8	63
404	-18	114	-5	69	-10	77	-9	72	433	1	64	-5	62	-4	65	-9	67
405	-11	85	-9	70	-7	81	-10	72	434	0	68	-8	66	-4	67	-6	68
406	-15	92	-8	66	-17	80	-18	75	435	-9	92	-8	76	-7	82	-10	79
407	-14	89	-10	68	-18	73	-12	71	436	-14	106	-5	85	-3	81	-3	78
408	-26	71	-19	73	-4	74	-11	63	437	-13	97	-6	81	-3	76	-8	74
409	-15	81	-12	69	-10	83	-5	70	438	-15	90	-10	77	-7	72	-9	72
410	-14	80	-16	70	-9	71	-17	75	439	-12	90	-7	81	-6	78	-10	72
411	0	68	-15	67	-9	67	-14	72	440	-18	88	-17	80	-12	72	-18	75
412	-14	70	-20	62	-1	61	-16	67	441	-10	73	-18	73	-14	68	-12	71
413	-24	56	-19	70	-8	66	-8	53	442	-9	79	-4	74	-3	70	-11	63
414	-23	68	-16	66	-14	66	-14	59	443	-14	86	-10	83	-6	76	-5	70
415	-24	50	-22	65	0	59	-9	52	444	-10	73	-9	71	-5	66	-17	75
416	-11	74	-20	63	2	59	-11	68	445	-10	70	-9	67	-5	62	-14	72
417	23	-13	9	-2	17	-10	9	-2	446	-10	69	-1	61	0	57	-16	67
418	26	-13	26	-9	32	-13	30	-10	447	-5	66	-8	66	-4	61	-8	53
419	40	-15	33	-9	42	-9	31	-4	448	-9	64	-14	66	-9	60	-14	59
420	49	-14	39	-7	49	-5	33	-1	449	-5	58	0	59	1	54	-9	52
421	44	3	41	-2	53	0	33	7	450	2	59	2	59	2	58	-11	68
422	45	6	45	3	64	3	31	12	451	21	-10	21	-13	17	-10	9	-2
423	44	34	49	9	68	10	37	23	452	24	-11	33	-14	32	-13	30	-10
424	33	54	45	27	66	27	31	38	453	28	-8	39	-7	42	-9	31	-4
425	19	82	36	59	47	57	20	64	454	28	-1	46	-2	49	-5	33	-1
426	-3	75	-6	66	-5	71	-9	71	455	29	3	51	2	53	0	33	7
427	-1	23	-7	35	0	24	-7	37	456	29	9	60	6	64	3	31	12
428	1	34	-7	42	-1	36	-8	44	457	35	20	61	17	68	10	37	23
429	1	43	-8	45	-2	42	-11	49	458	29	36	55	34	66	27	31	38
430	0	54	-5	48	-2	52	-10	56	459	14	67	42	62	47	57	20	64

9.3.1.2 Initialisation process for the arithmetic decoding engine

This process is invoked before decoding the first macroblock of a slice or after the decoding of any pcm_alignment_zero_bit and all pcm_sample_luma and pcm_sample_chroma data for a macroblock of type I_PCM.

Outputs of this process are the initialised decoding engine registers codIRange and codIOffset both in 16 bit register precision.

The status of the arithmetic decoding engine is represented by the variables codIRange and codIOffset. In the initialisation procedure of the arithmetic decoding process, codIRange is set equal to 0x01FE and codIOffset is set equal

to the value returned from `read_bits(9)` interpreted as a 9 bit binary representation of an unsigned integer with most significant bit written first.

The bitstream shall not contain data that results in a value of `codIOffset` being equal to 0x01FE or 0x01FF.

NOTE – The description of the arithmetic decoding engine in this Recommendation | International Standard utilizes 16 bit register precision. However, the minimum register precision for the variables `codIRange` and `codIOffset` is 9 bits.

9.3.2 Binarization process

Input to this process is a request for a syntax element.

Output of this process is the binarization of the syntax element, `maxBinIdxCtx`, `ctxIdxOffset`, and `bypassFlag`.

Table 9-25 specifies the type of binarization process, `maxBinIdxCtx`, and `ctxIdxOffset` associated with each syntax element.

The specification of the unary (U) binarization process, the truncated unary (TU) binarization process, the concatenated unary / k-th order Exp-Golomb (UEGk) binarization process, and the fixed-length (FL) binarization process are given in subclauses 9.3.2.1 to 9.3.2.4, respectively. Other binarizations are specified in subclauses 9.3.2.5 to 9.3.2.7.

Except for I slices, the binarizations for the syntax element `mb_type` as specified in subclause 9.3.2.5 consist of bin strings given by a concatenation of prefix and suffix bit strings. The UEGk binarization as specified in 9.3.2.3, which is used for the binarization of the syntax elements `mvd_IX` ($X = 0, 1$) and `coeff_abs_level_minus1`, and the binarization of the `coded_block_pattern` also consist of a concatenation of prefix and suffix bit strings. For these binarization processes, the prefix and the suffix bit string are separately indexed using the `binIdx` variable as specified further in subclause 9.3.3. The two sets of prefix bit strings and suffix bit strings are referred to as the binarization prefix part and the binarization suffix part, respectively.

Associated with each binarization or binarization part of a syntax element is a specific value of the context index offset (`ctxIdxOffset`) variable and a specific value of the `maxBinIdxCtx` variable as given in Table 9-25. When two values for each of these variables are specified for one syntax element in Table 9-25, the value in the upper row is related to the prefix part while the value in the lower row is related to the suffix part of the binarization of the corresponding syntax element.

The use of the `DecodeBypass` process and the variable `bypassFlag` is derived as follows.

- If no value is assigned to `ctxIdxOffset` for the corresponding binarization or binarization part in Table 9-25 labelled as “na”, all bins of the bit strings of the corresponding binarization or of the binarization prefix/suffix part are decoded by invoking the `DecodeBypass` process as specified in subclause 9.3.3.2.3. In such a case, `bypassFlag` is set equal to 1, where `bypassFlag` is used to indicate that for parsing the value of the bin from the bitstream the `DecodeBypass` process is applied.
- Otherwise, for each possible value of `binIdx` up to the specified value of `maxBinIdxCtx` given in Table 9-25, a specific value of the variable `ctxIdx` is further specified in subclause 9.3.3. `bypassFlag` is set equal to 0.

The possible values of the context index `ctxIdx` are in the range 0 to 459, inclusive. The value assigned to `ctxIdxOffset` specifies the lower value of the range of `ctxIdx` assigned to the corresponding binarization or binarization part of a syntax element.

`ctxIdx = ctxIdxOffset = 276` is assigned to the syntax element `end_of_slice_flag` and the bin of `mb_type`, which specifies the I_PCM macroblock type as further specified in subclause 9.3.3.1. For parsing the value of the corresponding bin from the bitstream, the arithmetic decoding process for decisions before termination (`DecodeTerminate`) as specified in subclause 9.3.3.2.4 is applied.

NOTE – The bins of `mb_type` in I slices and the bins of the suffix for `mb_type` in SI slices that correspond to the same value of `binIdx` share the same `ctxIdx`. The last bin of the prefix of `mb_type` and the first bin of the suffix of `mb_type` in P, SP, and B slices may share the same `ctxIdx`.

Table 9-25 – Syntax elements and associated types of binarization, maxBinIdxCtx, and ctxIdxOffset

Syntax element	Type of binarization	maxBinIdxCtx	ctxIdxOffset
mb_type (SI slices only)	prefix and suffix as specified in subclause 9.3.2.5	prefix: 0 suffix: 6	prefix: 0 suffix: 3
mb_type (I slices only)	as specified in subclause 9.3.2.5	6	3
mb_skip_flag (P, SP slices only)	FL, cMax=1	0	11
mb_type (P, SP slices only)	prefix and suffix as specified in subclause 9.3.2.5	prefix: 2 suffix: 5	prefix: 14 suffix: 17
sub_mb_type (P, SP slices only)	as specified in subclause 9.3.2.5	2	21
mb_skip_flag (B slices only)	FL, cMax=1	0	24
mb_type (B slices only)	prefix and suffix as specified in subclause 9.3.2.5	prefix: 3 suffix: 5	prefix: 27 suffix: 32
sub_mb_type (B slices only)	as specified in subclause 9.3.2.5	3	36
mvd_10[][][0], mvd_11[][][0]	prefix and suffix as given by UEG3 with signedValFlag=1, uCoff=9	prefix: 4 suffix: na	prefix: 40 suffix: na (uses DecodeBypass)
mvd_10[][][1], mvd_11[][][1]		prefix: 4 suffix: na	prefix: 47 suffix: na (uses DecodeBypass)
ref_idx_l0, ref_idx_l1	U	2	54
mb_qp_delta	as specified in subclause 9.3.2.7	2	60
intra_chroma_pred_mode	TU, cMax=3	1	64
prev_intra4x4_pred_mode_flag, prev_intra8x8_pred_mode_flag	FL, cMax=1	0	68
rem_intra4x4_pred_mode, rem_intra8x8_pred_mode	FL, cMax=7	0	69
mb_field_decoding_flag	FL, cMax=1	0	70
coded_block_pattern	prefix and suffix as specified in subclause 9.3.2.6	prefix: 3 suffix: 1	prefix: 73 suffix: 77
coded_block_flag	FL, cMax=1	0	85
significant_coeff_flag (frame coded blocks with ctxBlockCat < 5)	FL, cMax=1	0	105
last_significant_coeff_flag (frame coded blocks with ctxBlockCat < 5)	FL, cMax=1	0	166
coeff_abs_level_minus1 (blocks with ctxBlockCat < 5)	prefix and suffix as given by UEG0 with signedValFlag=0, uCoff=14	prefix: 1 suffix: na	prefix: 227 suffix: na, (uses DecodeBypass)
coeff_sign_flag	FL, cMax=1	0	na, (uses DecodeBypass)
end_of_slice_flag	FL, cMax=1	0	276
significant_coeff_flag (field coded blocks with ctxBlockCat < 5)	FL, cMax=1	0	277

Syntax element	Type of binarization	maxBinIdxCtx	ctxIdxOffset
last_significant_coeff_flag (field coded blocks with ctxBlockCat < 5)	FL, cMax=1	0	338
transform_size_8x8_flag	FL, cMax=1	0	399
significant_coeff_flag (frame coded blocks with ctxBlockCat == 5)	FL, cMax=1	0	402
last_significant_coeff_flag (frame coded blocks with ctxBlockCat == 5)	FL, cMax=1	0	417
coeff_abs_level_minus1 (blocks with ctxBlockCat == 5)	prefix and suffix as given by UEG0 with signedValFlag=0, uCoff=14	prefix: 1 suffix: na	prefix: 426 suffix: na, (uses DecodeBypass)
significant_coeff_flag (field coded blocks with ctxBlockCat == 5)	FL, cMax=1	0	436
last_significant_coeff_flag (field coded blocks with ctxBlockCat == 5)	FL, cMax=1	0	451

9.3.2.1 Unary (U) binarization process

Input to this process is a request for a U binarization for a syntax element.

Output of this process is the U binarization of the syntax element.

The bin string of a syntax element having (unsigned integer) value synEIVal is a bit string of length synEIVal + 1 indexed by BinIdx. The bins for binIdx less than synEIVal are equal to 1. The bin with binIdx equal to synEIVal is equal to 0.

Table 9-26 illustrates the bin strings of the unary binarization for a syntax element.

Table 9-26 – Bin string of the unary binarization (informative)

Value of syntax element	Bin string					
0 (I_NxN)	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

9.3.2.2 Truncated unary (TU) binarization process

Input to this process is a request for a TU binarization for a syntax element and cMax.

Output of this process is the TU binarization of the syntax element.

For syntax element (unsigned integer) values less than cMax, the U binarization process as specified in subclause 9.3.2.1 is invoked. For the syntax element value equal to cMax the bin string is a bit string of length cMax with all bins being equal to 1.

NOTE – TU binarization is always invoked with a cMax value equal to the largest possible value of the syntax element being decoded.

9.3.2.3 Concatenated unary/ k-th order Exp-Golomb (UEGk) binarization process

Input to this process is a request for a UEGk binarization for a syntax element, signedValFlag and uCoff.

Output of this process is the UEGk binarization of the syntax element.

A UEGk bin string is a concatenation of a prefix bit string and a suffix bit string. The prefix of the binarization is specified by invoking the TU binarization process for the prefix part $\text{Min}(\text{uCoff}, \text{Abs}(\text{synElVal}))$ of a syntax element value synElVal as specified in subclause 9.3.2.2 with cMax = uCoff, where uCoff > 0.

The UEGk bin string is derived as follows.

- If one of the following is true, the bin string of a syntax element having value synElVal consists only of a prefix bit string,
 - signedValFlag is equal to 0 and the prefix bit string is not equal to the bit string of length uCoff with all bits equal to 1.
 - signedValFlag is equal to 1 and the prefix bit string is equal to the bit string that consists of a single bit with value equal to 0.
- Otherwise, the bin string of the UEGk suffix part of a syntax element value synElVal is specified by a process equivalent to the following pseudo-code:

```
if( Abs( synElVal ) >= uCoff ) {
    sufS = Abs( synElVal ) - uCoff
    stopLoop = 0
    do {
        if( sufS >= ( 1 << k ) ) {
            put( 1 )
            sufS = sufS - ( 1 << k )
            k++
        } else {
            put( 0 )
            while( k-- )
                put( ( sufS >> k ) & 0x01 )
            stopLoop = 1
        }
    } while( !stopLoop )
}
if( signedValFlag && synElVal != 0 )
    if( synElVal > 0 )
        put( 0 )
    else
        put( 1 )
```

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 9.1.

9.3.2.4 Fixed-length (FL) binarization process

Input to this process is 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 an fixedLength-bit unsigned integer bin string of the syntax element value, where $\text{fixedLength} = \text{Ceil}(\text{Log}_2(\text{cMax} + 1))$. The indexing of bins for the FL binarization is such that the binIdx = 0 relates to the least significant bit with increasing values of binIdx towards the most significant bit.

9.3.2.5 Binarization process for macroblock type and sub-macroblock type

Input to this process is a request for a binarization for syntax elements mb_type or sub_mb_type.

Output of this process is the binarization of the syntax element.

The binarization scheme for decoding of macroblock type in I slices is specified in Table 9-27.

For macroblock types in SI slices, the binarization consists of bin strings specified as a concatenation of a prefix and a suffix bit string as follows.

The prefix bit string consists of a single bit, which is specified by $b_0 = ((mb_type == SI) ? 0 : 1)$. For the syntax element value for which b_0 is equal to 0, the bin string only consists of the prefix bit string. For the syntax element value for which b_0 is equal to 1, the binarization is given by concatenating the prefix b_0 and the suffix bit string as specified in Table 9-27 for macroblock type in I slices indexed by subtracting 1 from the value of mb_type in SI slices.

Table 9-27 – Binarization for macroblock types in I slices

Value (name) of mb_type	Bin string						
0 (I_4x4)	0						
1 (I_16x16_0_0_0)	1	0	0	0	0	0	
2 (I_16x16_1_0_0)	1	0	0	0	0	1	
3 (I_16x16_2_0_0)	1	0	0	0	1	0	
4 (I_16x16_3_0_0)	1	0	0	0	1	1	
5 (I_16x16_0_1_0)	1	0	0	1	0	0	0
6 (I_16x16_1_1_0)	1	0	0	1	0	0	1
7 (I_16x16_2_1_0)	1	0	0	1	0	1	0
8 (I_16x16_3_1_0)	1	0	0	1	0	1	1
9 (I_16x16_0_2_0)	1	0	0	1	1	0	0
10 (I_16x16_1_2_0)	1	0	0	1	1	0	1
11 (I_16x16_2_2_0)	1	0	0	1	1	1	0
12 (I_16x16_3_2_0)	1	0	0	1	1	1	1
13 (I_16x16_0_0_1)	1	0	1	0	0	0	
14 (I_16x16_1_0_1)	1	0	1	0	0	1	
15 (I_16x16_2_0_1)	1	0	1	0	1	0	
16 (I_16x16_3_0_1)	1	0	1	0	1	1	
17 (I_16x16_0_1_1)	1	0	1	1	0	0	0
18 (I_16x16_1_1_1)	1	0	1	1	0	0	1
19 (I_16x16_2_1_1)	1	0	1	1	0	1	0
20 (I_16x16_3_1_1)	1	0	1	1	0	1	1
21 (I_16x16_0_2_1)	1	0	1	1	1	0	0
22 (I_16x16_1_2_1)	1	0	1	1	1	0	1
23 (I_16x16_2_2_1)	1	0	1	1	1	1	0
24 (I_16x16_3_2_1)	1	0	1	1	1	1	1
25 (I_PCM)	1	1					
binIdx	0	1	2	3	4	5	6

The binarization schemes for P macroblock types in P and SP slices and for B macroblocks in B slices are specified in Table 9-28.

The bin string for I macroblock types in P and SP slices corresponding to mb_type values 5 to 30 consists of a concatenation of a prefix, which consists of a single bit with value equal to 1 as specified in Table 9-28 and a suffix as specified in Table 9-27, indexed by subtracting 5 from the value of mb_type .

mb_type equal to 4 (P_8x8ref0) is not allowed.

For I macroblock types in B slices (mb_type values 23 to 48) the binarization consists of bin strings specified as a concatenation of a prefix bit string as specified in Table 9-28 and suffix bit strings as specified in Table 9-27, indexed by subtracting 23 from the value of mb_type.

Table 9-28 – Binarization for macroblock types in P, SP, and B slices

Slice type	Value (name) of mb_type	Bin string							
P, SP slice	0 (P_L0_16x16)	0	0	0					
	1 (P_L0_L0_16x8)	0	1	1					
	2 (P_L0_L0_8x16)	0	1	0					
	3 (P_8x8)	0	0	1					
	4 (P_8x8ref0)	na							
	5 to 30 (Intra, prefix only)	1							
B slice	0 (B_Direct_16x16)	0							
	1 (B_L0_16x16)	1	0	0					
	2 (B_L1_16x16)	1	0	1					
	3 (B_Bi_16x16)	1	1	0	0	0	0		
	4 (B_L0_L0_16x8)	1	1	0	0	0	1		
	5 (B_L0_L0_8x16)	1	1	0	0	1	0		
	6 (B_L1_L1_16x8)	1	1	0	0	1	1		
	7 (B_L1_L1_8x16)	1	1	0	1	0	0		
	8 (B_L0_L1_16x8)	1	1	0	1	0	1		
	9 (B_L0_L1_8x16)	1	1	0	1	1	0		
	10 (B_L1_L0_16x8)	1	1	0	1	1	1		
	11 (B_L1_L0_8x16)	1	1	1	1	1	0		
	12 (B_L0_Bi_16x8)	1	1	1	0	0	0	0	
	13 (B_L0_Bi_8x16)	1	1	1	0	0	0	1	
	14 (B_L1_Bi_16x8)	1	1	1	0	0	1	0	
	15 (B_L1_Bi_8x16)	1	1	1	0	0	1	1	
	16 (B_Bi_L0_16x8)	1	1	1	0	1	0	0	
	17 (B_Bi_L0_8x16)	1	1	1	0	1	0	1	
	18 (B_Bi_L1_16x8)	1	1	1	0	1	1	0	
	19 (B_Bi_L1_8x16)	1	1	1	0	1	1	1	
	20 (B_Bi_Bi_16x8)	1	1	1	1	0	0	0	
	21 (B_Bi_Bi_8x16)	1	1	1	1	0	0	1	
22 (B_8x8)	1	1	1	1	1	1			
23 to 48 (Intra, prefix only)	1	1	1	1	0	1			
binIdx		0	1	2	3	4	5	6	

For P, SP, and B slices the specification of the binarization for sub_mb_type is given in Table 9-29.

Table 9-29 – Binarization for sub-macroblock types in P, SP, and B slices

Slice type	Value (name) of sub_mb_type	Bin string					
P, SP slice	0 (P_L0_8x8)	1					
	1 (P_L0_8x4)	0	0				
	2 (P_L0_4x8)	0	1	1			
	3 (P_L0_4x4)	0	1	0			
B slice	0 (B_Direct_8x8)	0					
	1 (B_L0_8x8)	1	0	0			
	2 (B_L1_8x8)	1	0	1			
	3 (B_Bi_8x8)	1	1	0	0	0	
	4 (B_L0_8x4)	1	1	0	0	1	
	5 (B_L0_4x8)	1	1	0	1	0	
	6 (B_L1_8x4)	1	1	0	1	1	
	7 (B_L1_4x8)	1	1	1	0	0	0
	8 (B_Bi_8x4)	1	1	1	0	0	1
	9 (B_Bi_4x8)	1	1	1	0	1	0
	10 (B_L0_4x4)	1	1	1	0	1	1
	11 (B_L1_4x4)	1	1	1	1	0	
12 (B_Bi_4x4)	1	1	1	1	1		
binIdx		0	1	2	3	4	5

9.3.2.6 Binarization process for coded block pattern

Input to this process is a request for a binarization for the syntax element `coded_block_pattern`.

Output of this process is the binarization of the syntax element.

The binarization of `coded_block_pattern` consists of a prefix part and (when present) a suffix part. The prefix part of the binarization is given by the FL binarization of `CodedBlockPatternLuma` with `cMax = 15`. When `chroma_format_idc` is not equal to 0 (monochrome), the suffix part is present and consists of the TU binarization of `CodedBlockPatternChroma` with `cMax = 2`. The relationship between the value of the syntax element `coded_block_pattern` and the values of `CodedBlockPatternLuma` and `CodedBlockPatternChroma` is given as specified in subclause 7.4.5.

9.3.2.7 Binarization process for mb_qp_delta

Input to this process is a request for a binarization for the syntax element `mb_qp_delta`.

Output of this process is the binarization of the syntax element.

The bin string of `mb_qp_delta` is derived by the U binarization of the mapped value of the syntax element `mb_qp_delta`, where the assignment rule between the signed value of `mb_qp_delta` and its mapped value is given as specified in Table 9-3.

9.3.3 Decoding process flow

Input to this process is a binarization of the requested syntax element, `maxBinIdxCtx`, `bypassFlag` and `ctxIdxOffset` as specified in subclause 9.3.2.

Output of this process is the value of the syntax element.

This process specifies how each bit of a bit string is parsed for each syntax element.

After parsing each bit, the resulting bit string is compared to all bin strings of the binarization of the syntax element and the following applies.

- If the bit string is equal to one of the bin strings, the corresponding value of the syntax element is the output.
- Otherwise (the bit 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.

When the binarization of the corresponding syntax element consists of a prefix and a suffix binarization part, the variable `binIdx` is set equal to 0 for the first bin of each part of the bin string (prefix part or suffix part). In this case, after parsing the prefix bit string, the parsing process of the suffix bit string related to the binarizations specified in subclauses 9.3.2.3 and 9.3.2.5 is invoked depending on the resulting prefix bit string as specified in subclauses 9.3.2.3 and 9.3.2.5. Note that for the binarization of the syntax element `coded_block_pattern`, the suffix bit string is present regardless of the prefix bit string of length 4 as specified in subclause 9.3.2.6.

Depending on the variable `bypassFlag`, the following applies.

- If `bypassFlag` is equal to 1, the bypass decoding process as specified in subclause 9.3.3.2.3 is applied for parsing the value of the bins from the bitstream.
- Otherwise (`bypassFlag` is equal to 0), the parsing of each bin is specified by the following two ordered steps:
 1. Given `binIdx`, `maxBinIdxCtx` and `ctxIdxOffset`, `ctxIdx` is derived as specified in subclause 9.3.3.1.
 2. Given `ctxIdx`, the value of the bin from the bitstream as specified in subclause 9.3.3.2 is decoded.

9.3.3.1 Derivation process for `ctxIdx`

Inputs to this process are `binIdx`, `maxBinIdxCtx` and `ctxIdxOffset`.

Output of this process is `ctxIdx`.

Table 9-30 shows the assignment of `ctxIdx` increments (`ctxIdxInc`) to `binIdx` for all `ctxIdxOffset` values except those related to the syntax elements `coded_block_flag`, `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1`.

The `ctxIdx` to be used with a specific `binIdx` is specified by first determining the `ctxIdxOffset` associated with the given bin string or part thereof. The `ctxIdx` is determined as follows.

- If the `ctxIdxOffset` is listed in Table 9-30, the `ctxIdx` for a `binIdx` is the sum of `ctxIdxOffset` and `ctxIdxInc`, which is found in Table 9-30. When more than one value is listed in Table 9-30 for a `binIdx`, the assignment process for `ctxIdxInc` for that `binIdx` is further specified in the subclauses given in parenthesis of the corresponding table entry.
- Otherwise (`ctxIdxOffset` is not listed in Table 9-30), the `ctxIdx` is specified to be the sum of the following terms: `ctxIdxOffset` and `ctxIdxBlockCatOffset(ctxBlockCat)` as specified in Table 9-31 and `ctxIdxInc(ctxBlockCat)`. Subclause 9.3.3.1.3 specifies which `ctxBlockCat` is used. Subclause 9.3.3.1.1.9 specifies the assignment of `ctxIdxInc(ctxBlockCat)` for `coded_block_flag`, and subclause 9.3.3.1.3 specifies the assignment of `ctxIdxInc(ctxBlockCat)` for `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1`.

All bins with `binIdx` greater than `maxBinIdxCtx` are parsed using the value of `ctxIdx` being assigned to `binIdx` equal to `maxBinIdxCtx`.

All entries in Table 9-30 labelled with “na” correspond to values of `binIdx` that do not occur for the corresponding `ctxIdxOffset`.

`ctxIdx = 276` is assigned to the `binIdx` of `mb_type` indicating the `I_PCM` mode. For parsing the value of the corresponding bins from the bitstream, the arithmetic decoding process for decisions before termination as specified in subclause 9.3.3.2.4 is applied.

Table 9-30 – Assignment of ctxIdxInc to binIdx for all ctxIdxOffset values except those related to the syntax elements coded_block_flag, significant_coeff_flag, last_significant_coeff_flag, and coeff_abs_level_minus1

ctxIdxOffset	binIdx						
	0	1	2	3	4	5	>= 6
0	0,1,2 (subclause 9.3.3.1.1.3)	na	na	na	na	na	na
3	0,1,2 (subclause 9.3.3.1.1.3)	ctxIdx=276	3	4	5,6 (subclause 9.3.3.1.2)	6,7 (subclause 9.3.3.1.2)	7
11	0,1,2 (subclause 9.3.3.1.1.1)	na	na	na	na	na	na
14	0	1	2,3 (subclause 9.3.3.1.2)	na	na	na	na
17	0	ctxIdx=276	1	2	2,3 (subclause 9.3.3.1.2)	3	3
21	0	1	2	na	na	na	na
24	0,1,2 (subclause 9.3.3.1.1.1)	na	na	na	na	na	na
27	0,1,2 (subclause 9.3.3.1.1.3)	3	4,5 (subclause 9.3.3.1.2)	5	5	5	5
32	0	ctxIdx=276	1	2	2,3 (subclause 9.3.3.1.2)	3	3
36	0	1	2,3 (subclause 9.3.3.1.2)	3	3	3	na
40	0,1,2 (subclause 9.3.3.1.1.7)	3	4	5	6	6	6
47	0,1,2 (subclause 9.3.3.1.1.7)	3	4	5	6	6	6
54	0,1,2,3 (subclause 9.3.3.1.1.6)	4	5	5	5	5	5
60	0,1 (subclause 9.3.3.1.1.5)	2	3	3	3	3	3
64	0,1,2 (subclause 9.3.3.1.1.8)	3	3	na	na	na	na
68	0	na	na	na	na	na	na
69	0	0	0	na	na	na	na
70	0,1,2 (subclause 9.3.3.1.1.2)	na	na	na	na	na	na
73	0,1,2,3 (subclause 9.3.3.1.1.4)	0,1,2,3 (subclause 9.3.3.1.1.4)	0,1,2,3 (subclause 9.3.3.1.1.4)	0,1,2,3 (subclause 9.3.3.1.1.4)	na	na	na
77	0,1,2,3 (subclause 9.3.3.1.1.4)	4,5,6,7 (subclause 9.3.3.1.1.4)	na	na	na	na	na
276	0	na	na	na	na	na	na
399	0,1,2 (subclause 9.3.3.1.1.10)	na	na	na	na	na	na

Table 9-31 shows the values of `ctxIdxBlockCatOffset` depending on `ctxBlockCat` for the syntax elements `coded_block_flag`, `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1`. The specification of `ctxBlockCat` is given in Table 9-33.

Table 9-31 – Assignment of `ctxIdxBlockCatOffset` to `ctxBlockCat` for syntax elements `coded_block_flag`, `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1`

Syntax element	ctxBlockCat (as specified in Table 9-33)					
	0	1	2	3	4	5
<code>coded_block_flag</code>	0	4	8	12	16	na
<code>significant_coeff_flag</code>	0	15	29	44	47	0
<code>last_significant_coeff_flag</code>	0	15	29	44	47	0
<code>coeff_abs_level_minus1</code>	0	10	20	30	39	0

9.3.3.1.1 Assignment process of `ctxIdxInc` using neighbouring syntax elements

Subclause 9.3.3.1.1.1 specifies the derivation process of `ctxIdxInc` for the syntax element `mb_skip_flag`.

Subclause 9.3.3.1.1.2 specifies the derivation process of `ctxIdxInc` for the syntax element `mb_field_decoding_flag`.

Subclause 9.3.3.1.1.3 specifies the derivation process of `ctxIdxInc` for the syntax element `mb_type`.

Subclause 9.3.3.1.1.4 specifies the derivation process of `ctxIdxInc` for the syntax element `coded_block_pattern`.

Subclause 9.3.3.1.1.5 specifies the derivation process of `ctxIdxInc` for the syntax element `mb_qp_delta`.

Subclause 9.3.3.1.1.6 specifies the derivation process of `ctxIdxInc` for the syntax elements `ref_idx_10` and `ref_idx_11`.

Subclause 9.3.3.1.1.7 specifies the derivation process of `ctxIdxInc` for the syntax elements `mvd_10` and `mvd_11`.

Subclause 9.3.3.1.1.8 specifies the derivation process of `ctxIdxInc` for the syntax element `intra_chroma_pred_mode`.

Subclause 9.3.3.1.1.9 specifies the derivation process of `ctxIdxInc` for the syntax element `coded_block_flag`.

Subclause 9.3.3.1.1.10 specifies the derivation process of `ctxIdxInc` for the syntax element `transform_size_8x8_flag`.

9.3.3.1.1.1 Derivation process of `ctxIdxInc` for the syntax element `mb_skip_flag`

Output of this process is `ctxIdxInc`.

When `MbaffFrameFlag` is equal to 1 and `mb_field_decoding_flag` has not been decoded (yet) for the current macroblock pair with top macroblock address $2 * (\text{CurrMbAddr} / 2)$, the inference rule for the syntax element `mb_field_decoding_flag` as specified in subclause 7.4.4 is applied.

The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to `mbAddrA` and `mbAddrB`.

Let the variable `condTermFlagN` (with N being either A or B) be derived as follows.

- If `mbAddrN` is not available or `mb_skip_flag` for the macroblock `mbAddrN` is equal to 1, `condTermFlagN` is set equal to 0.
- Otherwise (`mbAddrN` is available and `mb_skip_flag` for the macroblock `mbAddrN` is equal to 0), `condTermFlagN` is set equal to 1.

The variable `ctxIdxInc` is derived by

$$\text{ctxIdxInc} = \text{condTermFlagA} + \text{condTermFlagB} \quad (9-1)$$

9.3.3.1.1.2 Derivation process of `ctxIdxInc` for the syntax element `mb_field_decoding_flag`

Output of this process is `ctxIdxInc`.

The derivation process for neighbouring macroblock addresses and their availability in MBAFF frames as specified in subclause 6.4.7 is invoked and the output is assigned to `mbAddrA` and `mbAddrB`.

When both macroblocks mbAddrN and mbAddrN + 1 have mb_type equal to P_Skip or B_Skip, the inference rule for the syntax element mb_field_decoding_flag as specified in subclause 7.4.4 is applied for the macroblock mbAddrN.

Let the variable condTermFlagN (with N being either A or B) be derived as follows.

- If any of the following conditions is true, condTermFlagN is set equal to 0,
 - mbAddrN is not available
 - the macroblock mbAddrN is a frame macroblock.
- Otherwise, condTermFlagN is set equal to 1.

The variable ctxIdxInc is derived by

$$\text{ctxIdxInc} = \text{condTermFlagA} + \text{condTermFlagB} \quad (9-2)$$

9.3.3.1.1.3 Derivation process of ctxIdxInc for the syntax element mb_type

Input to this process is ctxIdxOffset.

Output of this process is ctxIdxInc.

The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to mbAddrA and mbAddrB.

Let the variable condTermFlagN (with N being either A or B) be derived as follows.

- If any of the following conditions is true, condTermFlagN is set equal to 0
 - mbAddrN is not available
 - ctxIdxOffset is equal to 0 and mb_type for the macroblock mbAddrN is equal to SI
 - ctxIdxOffset is equal to 3 and mb_type for the macroblock mbAddrN is equal to I_NxN
 - ctxIdxOffset is equal to 27 and mb_type for the macroblock mbAddrN is equal to P_Skip, B_Skip, or B_Direct_16x16
- Otherwise, condTermFlagN is set equal to 1.

The variable ctxIdxInc is derived as

$$\text{ctxIdxInc} = \text{condTermFlagA} + \text{condTermFlagB} \quad (9-3)$$

9.3.3.1.1.4 Derivation process of ctxIdxInc for the syntax element coded_block_pattern

Inputs to this process are ctxIdxOffset and binIdx.

Output of this process is ctxIdxInc.

Depending on the value of the variable ctxIdxOffset, the following applies.

- If ctxIdxOffset is equal to 73, the following applies
 - The derivation process for neighbouring 8x8 luma blocks specified in subclause 6.4.8.2 is invoked with luma8x8BlkIdx = binIdx as input and the output is assigned to mbAddrA, mbAddrB, luma8x8BlkIdxA, and luma8x8BlkIdxB.
 - Let the variable condTermFlagN (with N being either A or B) be derived as follows.
 - If any of the following conditions are true, condTermFlagN is set equal to 0
 - mbAddrN is not available
 - mb_type for the macroblock mbAddrN is equal to I_PCM
 - the macroblock mbAddrN is not the current macroblock CurrMbAddr and the macroblock mbAddrN does not have mb_type equal to P_Skip or B_Skip, and ((CodedBlockPatternLuma >> luma8x8BlkIdxN) & 1) is not equal to 0 for the value of CodedBlockPatternLuma for the macroblock mbAddrN

- the macroblock mbAddrN is the current macroblock CurrMbAddr and the prior decoded bin value b_k of coded_block_pattern with $k = \text{luma8x8BlkIdxN}$ is not equal to 0.
- Otherwise, condTermFlagN is set equal to 1.
- The variable ctxIdxInc is derived as

$$\text{ctxIdxInc} = \text{condTermFlagA} + 2 * \text{condTermFlagB} \quad (9-4)$$

- Otherwise (ctxIdxOffset is equal to 77), the following applies.
 - The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to mbAddrA and mbAddrB.
 - Let the variable condTermFlagN (with N being either A or B) be derived as follows.
 - If mbAddrN is available and mb_type for the macroblock mbAddrN is equal to I_PCM, condTermFlagN is set equal to 1
 - Otherwise, if any of the following conditions is true, condTermFlagN is set equal to 0
 - mbAddrN is not available or the macroblock mbAddrN has mb_type equal to P_Skip or B_Skip
 - binIdx is equal to 0 and CodedBlockPatternChroma for the macroblock mbAddrN is equal to 0
 - binIdx is equal to 1 and CodedBlockPatternChroma for the macroblock mbAddrN is not equal to 2
 - Otherwise, condTermFlagN is set equal to 1.
 - The variable ctxIdxInc is derived as

$$\text{ctxIdxInc} = \text{condTermFlagA} + 2 * \text{condTermFlagB} + ((\text{binIdx} == 1) ? 4 : 0) \quad (9-5)$$

NOTE – When a macroblock uses an Intra_16x16 prediction mode, the values of CodedBlockPatternLuma and CodedBlockPatternChroma for the macroblock are derived from mb_type as specified in Table 7-11.

9.3.3.1.1.5 Derivation process of ctxIdxInc for the syntax element mb_qp_delta

Output of this process is ctxIdxInc.

Let prevMbAddr be the macroblock address of the macroblock that precedes the current macroblock in decoding order. When the current macroblock is the first macroblock of a slice, prevMbAddr is marked as not available.

Let the variable ctxIdxInc be derived as follows.

- If any of the following conditions is true, ctxIdxInc is set equal to 0
 - prevMbAddr is not available or the macroblock prevMbAddr has mb_type equal to P_Skip or B_Skip
 - mb_type of the macroblock prevMbAddr is equal to I_PCM
 - The macroblock prevMbAddr is not coded in Intra_16x16 prediction mode and both CodedBlockPatternLuma and CodedBlockPatternChroma for the macroblock prevMbAddr are equal to 0
 - mb_qp_delta for the macroblock prevMbAddr is equal to 0
- Otherwise, ctxIdxInc is set equal to 1.

9.3.3.1.1.6 Derivation process of ctxIdxInc for the syntax elements ref_idx_10 and ref_idx_11

Input to this process is mbPartIdx.

Output of this process is ctxIdxInc.

The interpretation of ref_idx_IX and Pred_LX within this subclause is specified as follows.

- If this process is invoked for the derivation of ref_idx_10, ref_idx_IX is interpreted as ref_idx_10 and Pred_LX is interpreted as Pred_L0.
- Otherwise (this process is invoked for the derivation of ref_idx_11), ref_idx_IX is interpreted as ref_idx_11 and Pred_LX is interpreted as Pred_L1.

Let currSubMbType be set equal to sub_mb_type[mbPartIdx].

The derivation process for neighbouring partitions specified in subclause 6.4.8.5 is invoked with `mbPartIdx`, `currSubMbType`, and `subMbPartIdx = 0` as input and the output is assigned to `mbAddrA\mbPartIdxA` and `mbAddrB\mbPartIdxB`.

With `ref_idx_IX[mbPartIdxN]` (with `N` being either `A` or `B`) specifying the syntax element for the macroblock `mbAddrN`, let the variable `refIdxZeroFlagN` be derived as follows.

- If `MbaffFrameFlag` is equal to 1, the current macroblock is a frame macroblock, and the macroblock `mbAddrN` is a field macroblock

$$\text{refIdxZeroFlagN} = ((\text{ref_idx_IX}[\text{mbPartIdxN}] > 1) ? 0 : 1) \quad (9-6)$$

- Otherwise,

$$\text{refIdxZeroFlagN} = ((\text{ref_idx_IX}[\text{mbPartIdxN}] > 0) ? 0 : 1) \quad (9-7)$$

Let the variable `predModeEqualFlagN` be specified as follows.

- If the macroblock `mbAddrN` has `mb_type` equal to `P_8x8` or `B_8x8`, the following applies.
 - If `SubMbPredMode(sub_mb_type[mbPartIdxN])` is not equal to `Pred_LX` and not equal to `BiPred`, `predModeEqualFlagN` is set equal to 0, where `sub_mb_type` specifies the syntax element for the macroblock `mbAddrN`.
 - Otherwise, `predModeEqualFlagN` is set equal to 1.
- Otherwise, the following applies.
 - If `MbPartPredMode(mb_type, mbPartIdxN)` is not equal to `Pred_LX` and not equal to `BiPred`, `predModeEqualFlagN` is set equal to 0, where `mb_type` specifies the syntax element for the macroblock `mbAddrN`.
 - Otherwise, `predModeEqualFlagN` is set equal to 1.

Let the variable `condTermFlagN` (with `N` being either `A` or `B`) be derived as follows.

- If any of the following conditions is true, `condTermFlagN` is set equal to 0
 - `mbAddrN` is not available
 - the macroblock `mbAddrN` has `mb_type` equal to `P_Skip` or `B_Skip`
 - The macroblock `mbAddrN` is coded in Intra prediction mode
 - `predModeEqualFlagN` is equal to 0
 - `refIdxZeroFlagN` is equal to 1
- Otherwise, `condTermFlagN` is set equal to 1.

The variable `ctxIdxInc` is derived as

$$\text{ctxIdxInc} = \text{condTermFlagA} + 2 * \text{condTermFlagB} \quad (9-8)$$

9.3.3.1.1.7 Derivation process of `ctxIdxInc` for the syntax elements `mvd_10` and `mvd_11`

Inputs to this process are `mbPartIdx`, `subMbPartIdx`, and `ctxIdxOffset`.

Output of this process is `ctxIdxInc`.

The interpretation of `mvd_IX` and `Pred_LX` within this subclause is specified as follows.

- If this process is invoked for the derivation of `mvd_10`, `mvd_IX` is interpreted as `mvd_10` and `Pred_LX` is interpreted as `Pred_L0`.
- Otherwise (this process is invoked for the derivation of `mvd_11`), `mvd_IX` is interpreted as `mvd_11` and `Pred_LX` is interpreted as `Pred_L1`.

Let `currSubMbType` be set equal to `sub_mb_type[mbPartIdx]`.

The derivation process for neighbouring partitions specified in subclause 6.4.8.5 is invoked with mbPartIdx, currSubMbType, and subMbPartIdx as input and the output is assigned to mbAddrA\mbPartIdxA\subMbPartIdxA and mbAddrB\mbPartIdxB\subMbPartIdxB.

Let the variable compIdx be derived as follows.

- If ctxIdxOffset is equal to 40, compIdx is set equal to 0.
- Otherwise (ctxIdxOffset is equal to 47), compIdx is set equal to 1.

Let the variable predModeEqualFlagN be specified as follows.

- If the macroblock mbAddrN has mb_type equal to P_8x8 or B_8x8, the following applies.
 - If SubMbPredMode(sub_mb_type[mbPartIdxN]) is not equal to Pred_LX and not equal to BiPred, predModeEqualFlagN is set equal to 0, where sub_mb_type specifies the syntax element for the macroblock mbAddrN.
 - Otherwise, predModeEqualFlagN is set equal to 1.
- Otherwise, the following applies.
 - If MbPartPredMode(mb_type, mbPartIdxN) is not equal to Pred_LX and not equal to BiPred, predModeEqualFlagN is set equal to 0, where mb_type specifies the syntax element for the macroblock mbAddrN.
 - Otherwise, predModeEqualFlagN is set equal to 1.

Let the variable absMvdCompN (with N being either A or B) be derived as follows.

- If any of the following conditions is true, absMvdCompN is set equal to 0
 - mbAddrN is not available
 - the macroblock mbAddrN has mb_type equal to P_Skip or B_Skip
 - The macroblock mbAddrN is coded in an Intra prediction mode
 - predModeEqualFlagN is equal to 0
- Otherwise, the following applies
 - If compIdx is equal to 1, MbaffFrameFlag is equal to 1, the current macroblock is a frame macroblock, and the macroblock mbAddrN is a field macroblock

$$\text{absMvdCompN} = \text{Abs}(\text{mvd_IX}[\text{mbPartIdxN}][\text{subMbPartIdxN}][\text{compIdx}]) * 2 \quad (9-9)$$

- Otherwise, if compIdx is equal to 1, MbaffFrameFlag is equal to 1, the current macroblock is a field macroblock, and the macroblock mbAddrN is a frame macroblock

$$\text{absMvdCompN} = \text{Abs}(\text{mvd_IX}[\text{mbPartIdxN}][\text{subMbPartIdxN}][\text{compIdx}]) / 2 \quad (9-10)$$

- Otherwise,

$$\text{absMvdCompN} = \text{Abs}(\text{mvd_IX}[\text{mbPartIdxN}][\text{subMbPartIdxN}][\text{compIdx}]) \quad (9-11)$$

The variable ctxIdxInc is derived as follows

- If (absMvdCompA + absMvdCompB) is less than 3, ctxIdxInc is set equal to 0.
- Otherwise, if (absMvdCompA + absMvdCompB) is greater than 32, ctxIdxInc is set equal to 2.
- Otherwise ((absMvdCompA + absMvdCompB) is in the range of 3 to 32, inclusive), ctxIdxInc is set equal to 1.

9.3.3.1.1.8 Derivation process of ctxIdxInc for the syntax element intra_chroma_pred_mode

Output of this process is ctxIdxInc.

The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to mbAddrA and mbAddrB.

Let the variable `condTermFlagN` (with `N` being replaced by either `A` or `B`) be derived as follows.

- If any of the following conditions is true, `condTermFlagN` is set equal to 0
 - `mbAddrN` is not available
 - The macroblock `mbAddrN` is coded in Inter prediction mode
 - `mb_type` for the macroblock `mbAddrN` is equal to `I_PCM`
 - `intra_chroma_pred_mode` for the macroblock `mbAddrN` is equal to 0
- Otherwise, `condTermFlagN` is set equal to 1.

The variable `ctxIdxInc` is derived by

$$\text{ctxIdxInc} = \text{condTermFlagA} + \text{condTermFlagB} \quad (9-12)$$

9.3.3.1.1.9 Derivation process of `ctxIdxInc` for the syntax element `coded_block_flag`

Input to this process is `ctxBlockCat` and additional input is specified as follows.

- If `ctxBlockCat` is equal to 0, no additional input
- Otherwise, if `ctxBlockCat` is equal to 1 or 2, `luma4x4BlkIdx`
- Otherwise, if `ctxBlockCat` is equal to 3, the chroma component index `iCbCr`
- Otherwise (`ctxBlockCat` is equal to 4), `chroma4x4BlkIdx` and the chroma component index `iCbCr`

Output of this process is `ctxIdxInc(ctxBlockCat)`.

Let the variable `transBlockN` (with `N` being either `A` or `B`) be derived as follows.

- If `ctxBlockCat` is equal to 0, the following applies.
 - The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to `mbAddrN` (with `N` being either `A` or `B`).
 - The variable `transBlockN` is derived as follows.
 - If `mbAddrN` is available and the macroblock `mbAddrN` is coded in `Intra_16x16` prediction mode, the luma DC block of macroblock `mbAddrN` is assigned to `transBlockN`
 - Otherwise, `transBlockN` is marked as not available.
- Otherwise, if `ctxBlockCat` is equal to 1 or 2, the following applies.
 - The derivation process for neighbouring 4x4 luma blocks specified in subclause 6.4.8.3 is invoked with `luma4x4BlkIdx` as input and the output is assigned to `mbAddrN`, `luma4x4BlkIdxN` (with `N` being either `A` or `B`).
 - The variable `transBlockN` is derived as follows.
 - If `mbAddrN` is available, the macroblock `mbAddrN` does not have `mb_type` equal to `P_Skip`, `B_Skip`, or `I_PCM`, $((\text{CodedBlockPatternLuma} \gg (\text{luma4x4BlkIdxN} \gg 2)) \& 1)$ is not equal to 0 for the macroblock `mbAddrN`, and `transform_size_8x8_flag` is equal to 0 for the macroblock `mbAddrN`, the 4x4 luma block with index `luma4x4BlkIdxN` of macroblock `mbAddrN` is assigned to `transBlockN`.
 - Otherwise, if `mbAddrN` is available, the macroblock `mbAddrN` does not have `mb_type` equal to `P_Skip` or `B_Skip`, $((\text{CodedBlockPatternLuma} \gg (\text{luma4x4BlkIdxN} \gg 2)) \& 1)$ is not equal to 0 for the macroblock `mbAddrN`, and `transform_size_8x8_flag` is equal to 1 for the macroblock `mbAddrN`, the 8x8 luma block with index $(\text{luma4x4BlkIdxN} \gg 2)$ of macroblock `mbAddrN` is assigned to `transBlockN`.
 - Otherwise, `transBlockN` is marked as not available.
- Otherwise, if `ctxBlockCat` is equal to 3, the following applies.
 - The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to `mbAddrN` (with `N` being either `A` or `B`).
 - The variable `transBlockN` is derived as follows.

- If mbAddrN is available, the macroblock mbAddrN does not have mb_type equal to P_Skip, B_Skip, or I_PCM, and CodedBlockPatternChroma is not equal to 0 for the macroblock mbAddrN, the chroma DC block of chroma component iCbCr of macroblock mbAddrN is assigned to transBlockN.
- Otherwise, transBlockN is marked as not available.
- Otherwise (ctxBlockCat is equal to 4), the following applies.
 - The derivation process for neighbouring 4x4 chroma blocks specified in subclause 6.4.8.4 is invoked with chroma4x4BlkIdx as input and the output is assigned to mbAddrN, chroma4x4BlkIdxN (with N being either A or B).
 - The variable transBlockN is derived as follows.
 - If mbAddrN is available, the macroblock mbAddrN does not have mb_type equal to P_Skip, B_Skip, or I_PCM, and CodedBlockPatternChroma is equal to 2 for the macroblock mbAddrN, the 4x4 chroma block with chroma4x4BlkIdxN of the chroma component iCbCr of macroblock mbAddrN is assigned to transBlockN.
 - Otherwise, transBlockN is marked as not available.

Let the variable condTermFlagN (with N being either A or B) be derived as follows.

- If any of the following conditions is true, condTermFlagN is set equal to 0
 - mbAddrN is not available and the current macroblock is coded in Inter prediction mode
 - mbAddrN is available and transBlockN is not available and mb_type for the macroblock mbAddrN is not equal to I_PCM
 - The current macroblock is coded in Intra prediction mode, constrained_intra_pred_flag is equal to 1, the macroblock mbAddrN is available and coded in Inter prediction mode, and slice data partitioning is in use (nal_unit_type is in the range of 2 through 4, inclusive).
- Otherwise, if any of the following conditions is true, condTermFlagN is set equal to 1
 - mbAddrN is not available and the current macroblock is coded in Intra prediction mode
 - mb_type for the macroblock mbAddrN is equal to I_PCM
- Otherwise, condTermFlagN is set equal to the value of the coded_block_flag of the transform block transBlockN that was decoded for the macroblock mbAddrN.

The variable ctxIdxInc(ctxBlockCat) is derived by

$$\text{ctxIdxInc}(\text{ctxBlockCat}) = \text{condTermFlagA} + 2 * \text{condTermFlagB} \quad (9-13)$$

9.3.3.1.1.10 Derivation process of ctxIdxInc for the syntax element transform_size_8x8_flag

Output of this process is ctxIdxInc.

The derivation process for neighbouring macroblocks specified in subclause 6.4.8.1 is invoked and the output is assigned to mbAddrA and mbAddrB.

Let the variable condTermFlagN (with N being either A or B) be derived as follows.

- If any of the following conditions is true, condTermFlagN is set equal to 0.
 - mbAddrN is not available
 - transform_size_8x8_flag for the macroblock mbAddrN is equal to 0
- Otherwise, condTermFlagN is set equal to 1.

The variable ctxIdxInc is derived by

$$\text{ctxIdxInc} = \text{condTermFlagA} + \text{condTermFlagB} \quad (9-14)$$

9.3.3.1.2 Assignment process of ctxIdxInc using prior decoded bin values

Inputs to this process are ctxIdxOffset and binIdx.

Output of this process is `ctxIdxInc`.

Table 9-32 contains the specification of `ctxIdxInc` for the given values of `ctxIdxOffset` and `binIdx`.

For each value of `ctxIdxOffset` and `binIdx`, `ctxIdxInc` is derived by using some of the values of prior decoded bin values ($b_0, b_1, b_2, \dots, b_k$), where the value of the index k is less than the value of `binIdx`.

Table 9-32 – Specification of `ctxIdxInc` for specific values of `ctxIdxOffset` and `binIdx`

Value (name) of <code>ctxIdxOffset</code>	<code>binIdx</code>	<code>ctxIdxInc</code>
3	4	$(b_3 \neq 0) ? 5 : 6$
	5	$(b_3 \neq 0) ? 6 : 7$
14	2	$(b_1 \neq 1) ? 2 : 3$
17	4	$(b_3 \neq 0) ? 2 : 3$
27	2	$(b_1 \neq 0) ? 4 : 5$
32	4	$(b_3 \neq 0) ? 2 : 3$
36	2	$(b_1 \neq 0) ? 2 : 3$

9.3.3.1.3 Assignment process of `ctxIdxInc` for syntax elements `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1`

Inputs to this process are `ctxIdxOffset` and `binIdx`.

Output of this process is `ctxIdxInc`.

The assignment process of `ctxIdxInc` for syntax elements `significant_coeff_flag`, `last_significant_coeff_flag`, and `coeff_abs_level_minus1` as well as for `coded_block_flag` depends on categories of different blocks denoted by the variable `ctxBlockCat`. The specification of these block categories is given in Table 9-33.

Table 9-33 – Specification of `ctxBlockCat` for the different blocks

Block description	<code>maxNumCoeff</code>	<code>ctxBlockCat</code>
block of luma DC transform coefficient levels (i.e., list <code>Intra16x16DCLevel</code> as described in subclause 7.4.5.3)	16	0
block of luma AC transform coefficient levels (i.e., list <code>Intra16x16ACLevel[i]</code> as described in subclause 7.4.5.3)	15	1
block of 16 luma transform coefficient levels (i.e., list <code>LumaLevel[i]</code> as described in subclause 7.4.5.3)	16	2
block of chroma DC transform coefficient levels	$4 * \text{NumC8x8}$	3
block of chroma AC transform coefficient levels	15	4
block of 64 luma transform coefficient levels (i.e., list <code>LumaLevel8x8[i]</code> as described in subclause 7.4.5.3)	64	5

Let the variable `levelListIdx` be set equal to the index of the list of transform coefficient levels as specified in subclause 7.4.5.3.

For the syntax elements `significant_coeff_flag` and `last_significant_coeff_flag` in blocks with `ctxBlockCat < 5` and `ctxBlockCat != 3`, the variable `ctxIdxInc` is derived by

$$\text{ctxIdxInc} = \text{levelListIdx} \quad (9-15)$$

where `levelListIdx` ranges from 0 to `maxNumCoeff – 2`, inclusive.

For the syntax elements `significant_coeff_flag` and `last_significant_coeff_flag` in blocks with `ctxBlockCat == 3`, the variable `ctxIdxInc` is derived by

$$\text{ctxIdxInc} = \text{Min}(\text{levelListIdx} / \text{NumC8x8}, 2) \quad (9-16)$$

where levelListIdx ranges from 0 to $4 * \text{NumC8x8} - 2$, inclusive.

For the syntax elements `significant_coeff_flag` and `last_significant_coeff_flag` in 8x8 luma blocks with `ctxBlockCat == 5`, Table 9-34 contains the specification of `ctxIdxInc` for the given values of `levelListIdx`, where `levelListIdx` ranges from 0 to 62, inclusive.

Table 9-34 – Mapping of scanning position to `ctxIdxInc` for `ctxBlockCat == 5`

levelListIdx	ctxIdxInc for significant_coeff_flag (frame coded macroblocks)	ctxIdxInc for significant_coeff_flag (field coded macroblocks)	ctxIdxInc for last_significant_coeff_flag	levelListIdx	ctxIdxInc for significant_coeff_flag (frame coded macroblocks)	ctxIdxInc for significant_coeff_flag (field coded macroblocks)	ctxIdxInc for last_significant_coeff_flag
0	0	0	0	32	7	9	3
1	1	1	1	33	6	9	3
2	2	1	1	34	11	10	3
3	3	2	1	35	12	10	3
4	4	2	1	36	13	8	3
5	5	3	1	37	11	11	3
6	5	3	1	38	6	12	3
7	4	4	1	39	7	11	3
8	4	5	1	40	8	9	4
9	3	6	1	41	9	9	4
10	3	7	1	42	14	10	4
11	4	7	1	43	10	10	4
12	4	7	1	44	9	8	4
13	4	8	1	45	8	13	4
14	5	4	1	46	6	13	4
15	5	5	1	47	11	9	4
16	4	6	2	48	12	9	5
17	4	9	2	49	13	10	5
18	4	10	2	50	11	10	5
19	4	10	2	51	6	8	5
20	3	8	2	52	9	13	6
21	3	11	2	53	14	13	6
22	6	12	2	54	10	9	6
23	7	11	2	55	9	9	6
24	7	9	2	56	11	10	7

levelIdx	ctxIdxInc for significant_coeff_flag (frame coded macroblocks)	ctxIdxInc for significant_coeff_flag (field coded macroblocks)	ctxIdxInc for last_significant_coeff_flag	levelIdx	ctxIdxInc for significant_coeff_flag (frame coded macroblocks)	ctxIdxInc for significant_coeff_flag (field coded macroblocks)	ctxIdxInc for last_significant_coeff_flag
25	7	9	2	57	12	10	7
26	8	10	2	58	13	14	7
27	9	10	2	59	11	14	7
28	10	8	2	60	14	14	8
29	9	11	2	61	10	14	8
30	8	12	2	62	12	14	8
31	7	11	2				

Let numDecodAbsLevelEq1 denotes the accumulated number of decoded transform coefficient levels with absolute value equal to 1, and let numDecodAbsLevelGt1 denotes the accumulated number of decoded transform coefficient levels with absolute value greater than 1. Both numbers are related to the same transform coefficient block, where the current decoding process takes place. Then, for decoding of coeff_abs_level_minus1, ctxIdxInc for coeff_abs_level_minus1 is specified depending on binIdx as follows.

- If binIdx is equal to 0, ctxIdxInc is derived by

$$\text{ctxIdxInc} = ((\text{numDecodAbsLevelGt1} \neq 0) ? 0 : \text{Min}(4, 1 + \text{numDecodAbsLevelEq1})) \quad (9-17)$$

- Otherwise (binIdx is greater than 0), ctxIdxInc is derived by

$$\text{ctxIdxInc} = 5 + \text{Min}(4 - (\text{ctxBlockCat} == 3), \text{numDecodAbsLevelGt1}) \quad (9-18)$$

9.3.3.2 Arithmetic decoding process

Inputs to this process are the bypassFlag, ctxIdx as derived in subclause 9.3.3.1, and the state variables codIRange and codIOffset of the arithmetic decoding engine.

Output of this process is the value of the bin.

Figure 9-2 illustrates the whole arithmetic decoding process for a single bin. For decoding the value of a bin, the context index ctxIdx is passed to the arithmetic decoding process DecodeBin(ctxIdx), which is specified as follows.

- If bypassFlag is equal to 1, DecodeBypass() as specified in subclause 9.3.3.2.3 is invoked.
- Otherwise, if bypassFlag is equal to 0 and ctxIdx is equal to 276, DecodeTerminate() as specified in subclause 9.3.3.2.4 is invoked.
- Otherwise (bypassFlag is equal to 0 and ctxIdx is not equal to 276), DecodeDecision() as specified in subclause 9.3.3.2.1 is applied.

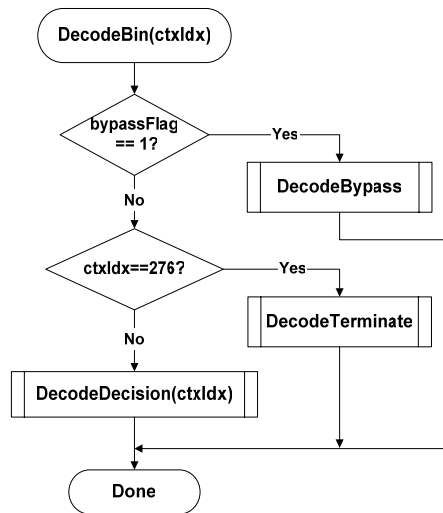


Figure 9-2 – Overview of the arithmetic decoding process for a single bin (informative)

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 codIRange will be subdivided into two sub-intervals having range $p(0) * \text{codIRange}$ and $\text{codIRange} - p(0) * \text{codIRange}$, 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 Recommendation | International Standard 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 $\{ p_{\text{LPS}}(p\text{StateIdx}) \mid 0 \leq p\text{StateIdx} < 64 \}$ for the LPS probability p_{LPS} . The numbering of the states is arranged in such a way that the probability state with index $p\text{StateIdx} = 0$ corresponds to an LPS probability value of 0.5, with decreasing LPS probability towards higher state indices.
- The range codIRange representing the state of the coding engine is quantised to a small set $\{Q_1, \dots, Q_4\}$ of pre-set quantisation values prior to the calculation of the new interval range. Storing a table containing all 64×4 pre-computed product values of $Q_i * p_{\text{LPS}}(p\text{StateIdx})$ allows a multiplication-free approximation of the product $\text{codIRange} * p_{\text{LPS}}(p\text{StateIdx})$.
- 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.

9.3.3.2.1 Arithmetic decoding process for a binary decision

Inputs to this process are ctxDx , codIRange , and codIOffset .

Outputs of this process are the decoded value binVal , and the updated variables codIRange and codIOffset .

Figure 9-3 shows the flowchart for decoding a single decision (DecodeDecision).

1. The value of the variable codIRangeLPS is derived as follows.
 - Given the current value of codIRange , the variable qCodIRangeIdx is derived by

$$\text{qCodIRangeIdx} = (\text{codIRange} \gg 6) \& 0x03 \quad (9-19)$$

- Given qCodIRangeIdx and $p\text{StateIdx}$ associated with ctxDx , the value of the variable rangeTabLPS as specified in Table 9-35 is assigned to codIRangeLPS :

$$\text{codIRangeLPS} = \text{rangeTabLPS}[p\text{StateIdx}][\text{qCodIRangeIdx}] \quad (9-20)$$

2. The variable `codIRange` is set equal to `codIRange - codIRangeLPS` and the following applies.
 - If `codIOffset` is greater than or equal to `codIRange`, the variable `binVal` is set equal to $1 - \text{valMPS}$, `codIOffset` is decremented by `codIRange`, and `codIRange` is set equal to `codIRangeLPS`.
 - Otherwise, the variable `binVal` is set equal to `valMPS`.

Given the value of `binVal`, the state transition is performed as specified in subclause 9.3.3.2.1.1. Depending on the current value of `codIRange`, renormalization is performed as specified in subclause 9.3.3.2.2.

9.3.3.2.1.1 State transition process

Inputs to this process are the current `pStateIdx`, the decoded value `binVal` and `valMPS` values of the context variable associated with `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 {
    if( pStateIdx == 0 )
        valMPS = 1 - valMPS
    pStateIdx = transIdxLPS( pStateIdx )
}
  
```

(9-21)

Table 9-36 specifies the transition rules `transIdxMPS()` and `transIdxLPS()` after decoding the value of `valMPS` and $1 - \text{valMPS}$, respectively.

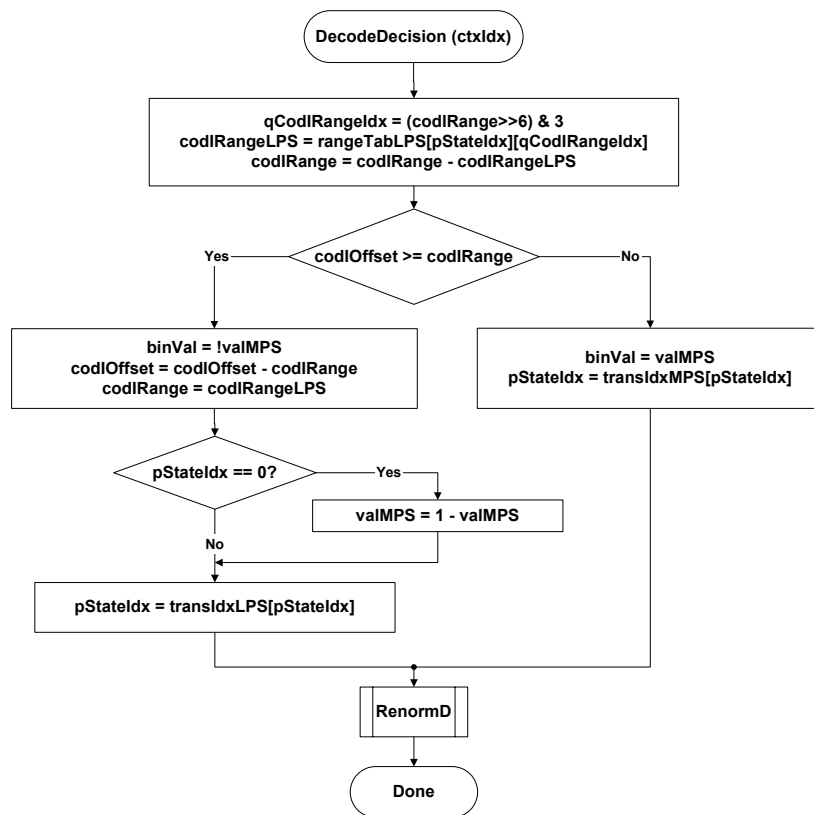


Figure 9-3 – Flowchart for decoding a decision

Table 9-35 – Specification of rangeTabLPS depending on pStateIdx and qCodIRangeIdx

pStateIdx	qCodIRangeIdx				pStateIdx	qCodIRangeIdx			
	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 9-36 – 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

9.3.3.2.2 Renormalization process in the arithmetic decoding engine

Inputs to this process are bits from slice data and the variables codIRange and codIOffset.

Outputs of this process are the updated variables codIRange and codIOffset.

A flowchart of the renormalization is shown in Figure 9-4. The current value of codIRange is first compared to 0x0100 and further steps are specified as follows.

- If codIRange is greater than or equal to 0x0100, no renormalization is needed and the RenormD process is finished;
- Otherwise (codIRange is less than 0x0100), the renormalization loop is entered. Within this loop, the value of codIRange is doubled, i.e., left-shifted by 1 and a single bit is shifted into codIOffset by using read_bits(1).

The bitstream shall not contain data that results in a value of codIOffset being greater than or equal to codIRange upon completion of this process.

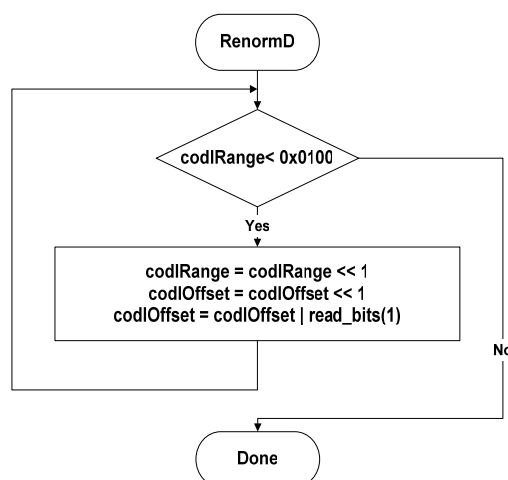


Figure 9-4 – Flowchart of renormalization

9.3.3.2.3 Bypass decoding process for binary decisions

Inputs to this process are bits from slice data and the variables `codIRange` and `codIOffset`.

Outputs of this process are the updated variable `codIOffset` and the decoded value `binVal`.

The bypass decoding process is invoked when `bypassFlag` is equal to 1. Figure 9-5 shows a flowchart of the corresponding process.

First, the value of `codIOffset` is doubled, i.e., left-shifted by 1 and a single bit is shifted into `codIOffset` by using `read_bits(1)`. Then, the value of `codIOffset` is compared to the value of `codIRange` and further steps are specified as follows.

- If `codIOffset` is greater than or equal to `codIRange`, the variable `binVal` is set equal to 1 and `codIOffset` is decremented by `codIRange`.
- Otherwise (`codIOffset` is less than `codIRange`), the variable `binVal` is set equal to 0.

The bitstream shall not contain data that results in a value of `codIOffset` being greater than or equal to `codIRange` upon completion of this process.

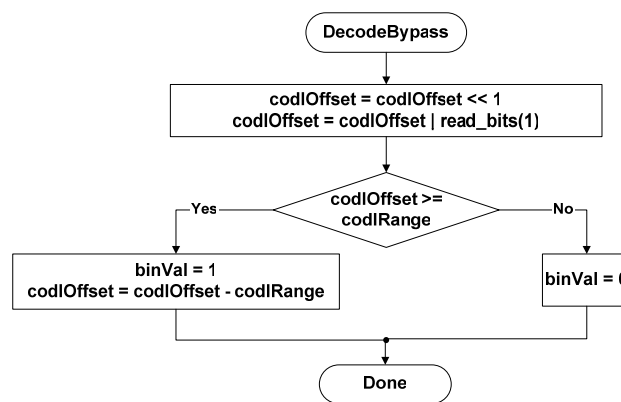


Figure 9-5 – Flowchart of bypass decoding process

9.3.3.2.4 Decoding process for binary decisions before termination

Inputs to this process are bits from slice data and the variables `codIRange` and `codIOffset`.

Outputs of this process are the updated variables `codIRange` and `codIOffset`, and the decoded value `binVal`.

This special decoding routine applies to decoding of `end_of_slice_flag` and of the bin indicating the `I_PCM` mode corresponding to `ctxIdx` equal to 276. Figure 9-6 shows the flowchart of the corresponding decoding process, which is specified as follows.

First, the value of `codIRange` is decremented by 2. Then, the value of `codIOffset` is compared to the value of `codIRange` and further steps are specified as follows.

- If `codIOffset` is greater than or equal to `codIRange`, the variable `binVal` is set equal to 1, no renormalization is carried out, and CABAC decoding is terminated. The last bit inserted in register `codIOffset` is equal to 1. When decoding `end_of_slice_flag`, this last bit inserted in register `codIOffset` is interpreted as `rbsp_stop_one_bit`.
- Otherwise (`codIOffset` is less than `codIRange`), the variable `binVal` is set equal to 0 and renormalization is performed as specified in subclause 9.3.3.2.2.

NOTE – This procedure may also be implemented using `DecodeDecision(ctxIdx)` with `ctxIdx = 276`. In the case where the decoded value is equal to 1, seven more bits would be read by `DecodeDecision(ctxIdx)` and a decoding process would have to adjust its bitstream pointer accordingly to properly decode following syntax elements.

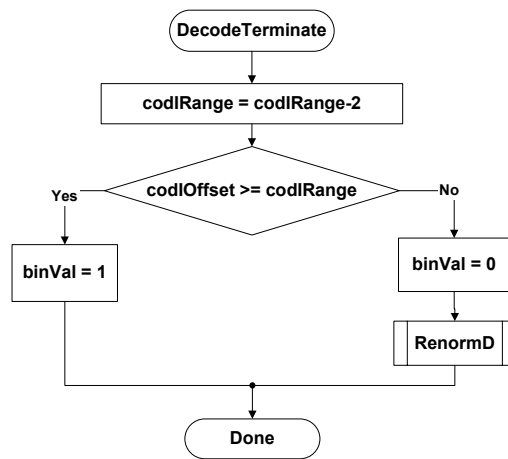


Figure 9-6 – Flowchart of decoding a decision before termination

9.3.4 Arithmetic encoding process (informative)

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

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 9.3.3.2. 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 section: 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 codILow pointing to the lower end of a sub-interval and a value of the variable codIRange specifying the corresponding range of that sub-interval.

9.3.4.1 Initialisation process for the arithmetic encoding engine (informative)

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

This process is invoked before encoding the first macroblock of a slice, and after encoding any pcm_alignment_zero_bit and all pcm_sample_luma and pcm_sample_chroma data for a macroblock of type I_PCM.

Outputs of this process are the values codILow, codIRange, firstBitFlag, bitsOutstanding, and symCnt of the arithmetic encoding engine.

In the initialisation procedure of the encoder, codILow is set equal to 0, and codIRange is set equal to 0x01FE. Furthermore, a firstBitFlag is set equal to 1, and bitsOutstanding and symCnt counters are set equal to 0.

NOTE – The minimum register precision required for codILow is 10 bits and for CodIRange is 9 bits. The precision required for the counters bitsOutstanding and symCnt 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, the minimum register precision required for the variables bitsOutstanding and symCnt is given by $\text{Ceil}(\text{Log}_2(\text{MaxBinCountInSlice} + 1))$.

9.3.4.2 Encoding process for a binary decision (informative)

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

Inputs to this process are the context index ctxIdx, the value of binVal to be encoded, and the variables codIRange, codILow and symCnt.

Outputs of this process are the variables codIRange, codILow, and symCnt.

Figure 9-7 shows the flowchart for encoding a single decision. In a first step, the variable codIRangeLPS is derived as follows.

Given the current value of codIRange, codIRange is mapped to the index qCodIRangeIdx of a quantised value of codIRange by using Equation 9-19. The value of qCodIRangeIdx and the value of pStateIdx associated with ctxIdx are

used to determine the value of the variable rangeTabLPS as specified in Table 9-35, which is assigned to codIRangeLPS. The value of codIRange – codIRangeLPS is assigned to codIRange.

In a second step, the value of binVal is compared to valMPS associated with ctxIdx. When binVal is different from valMPS, codIRange is added to codILow and codIRange is set equal to the value codIRangeLPS. Given the encoded decision, the state transition is performed as specified in subclause 9.3.3.2.1.1. Depending on the current value of codIRange, renormalization is performed as specified in subclause 9.3.4.3. Finally, the variable symCnt is incremented by 1.

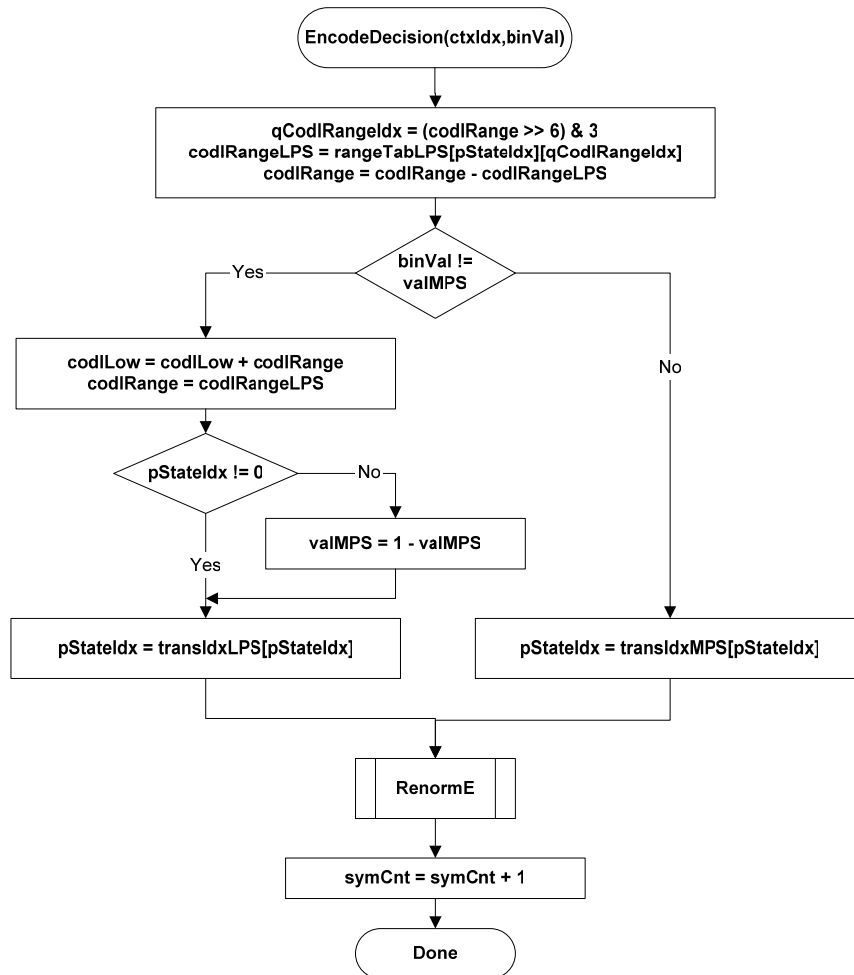


Figure 9-7 – Flowchart for encoding a decision

9.3.4.3 Renormalization process in the arithmetic encoding engine (informative)

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

Inputs to this process are the variables codIRange, codILow, firstBitFlag, and bitsOutstanding.

Outputs of this process are zero or more bits written to the RBSP and the updated variables codIRange, codILow, firstBitFlag, and bitsOutstanding.

Renormalization is illustrated in Figure 9-8.

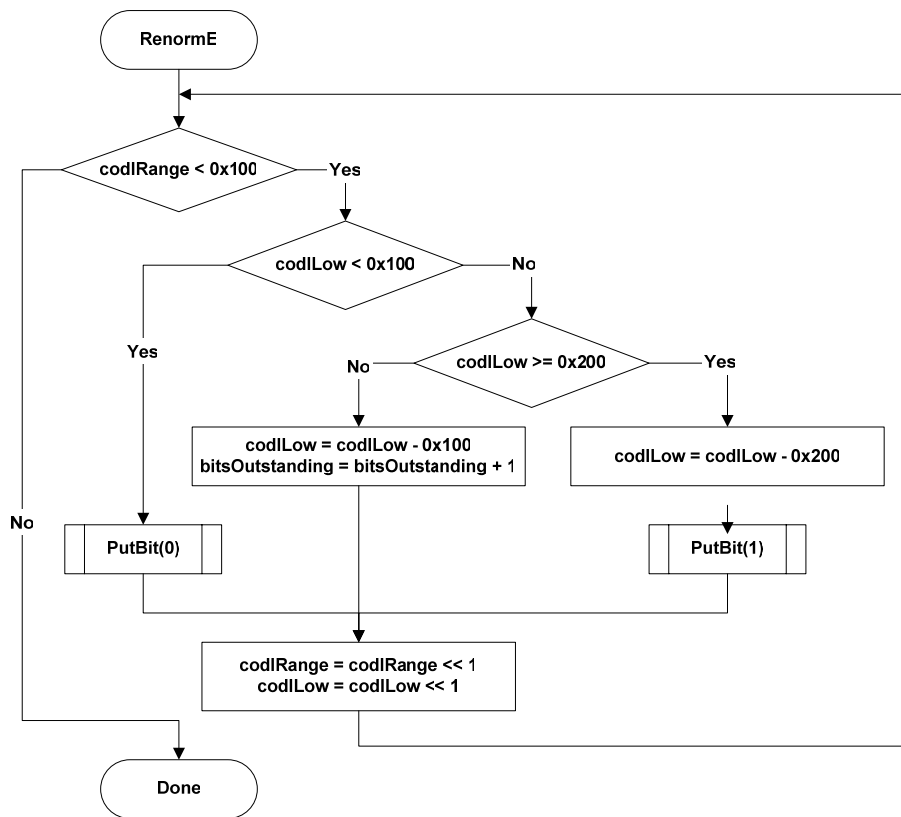


Figure 9-8 – Flowchart of renormalization in the encoder

The PutBit() procedure described in Figure 9-9 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.

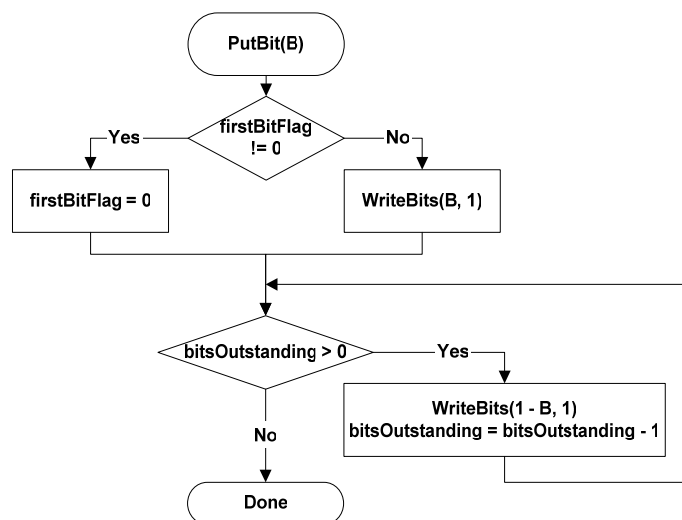


Figure 9-9 – Flowchart of PutBit(B)

9.3.4.4 Bypass encoding process for binary decisions (informative)

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

Inputs to this process are the variables `binVal`, `codILow`, `codIRange`, `bitsOutstanding`, and `symCnt`.

Output of this process is a bit written to the RBSP and the updated variables `codILow`, `bitsOutstanding`, and `symCnt`.

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 9-10.

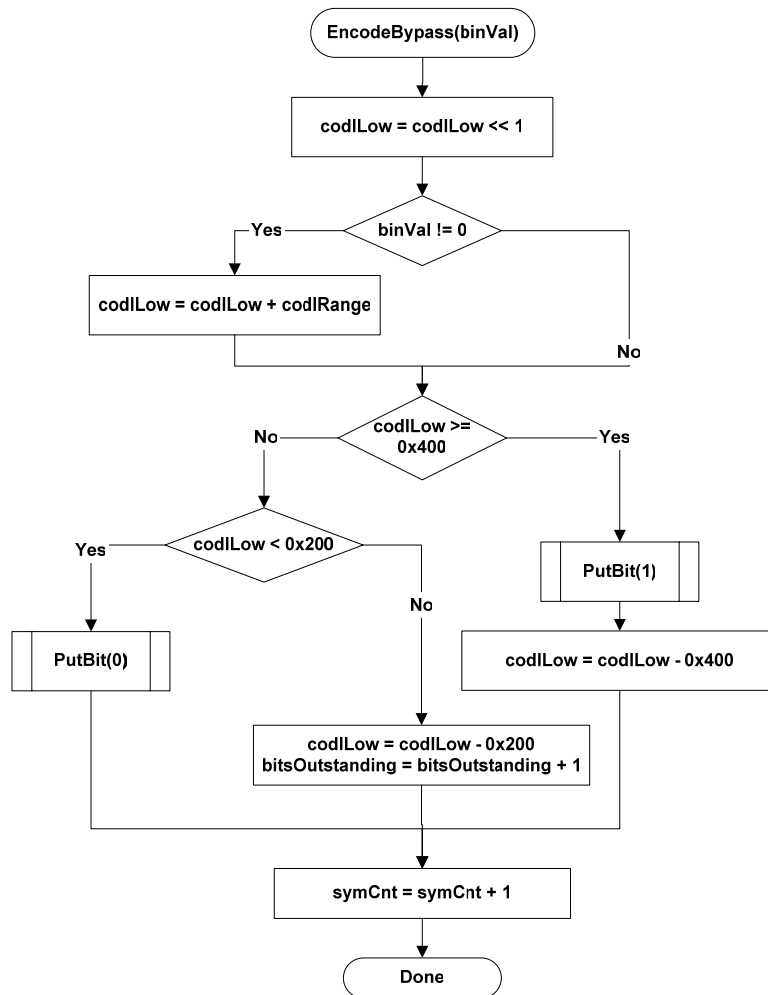


Figure 9-10 – Flowchart of encoding bypass

9.3.4.5 Encoding process for a binary decision before termination (informative)

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

Inputs to this process are the variables `binVal`, `codIRange`, `codILow`, `bitsOutstanding`, and `symCnt`.

Outputs of this process are zero or more bits written to the RBSP and the updated variables `codILow`, `codIRange`, `bitsOutstanding`, and `symCnt`.

This encoding routine shown in Figure 9-11 applies to encoding of the `end_of_slice_flag` and of the bin indicating the `I_PCM mb_type` both associated with `ctxIdx` equal to 276.

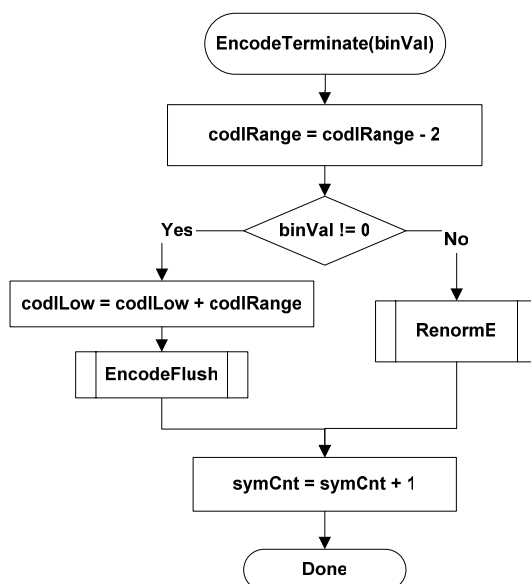


Figure 9-11 – Flowchart of encoding a decision before termination

When the value of binVal to encode is equal to 1, CABAC encoding is terminated and the flushing procedure shown in Figure 9-12 is applied. In this flushing procedure, the last bit written by WriteBits(B, N) is equal to 1. When encoding end_of_slice_flag, this last bit is interpreted as the rbsp_stop_one_bit.

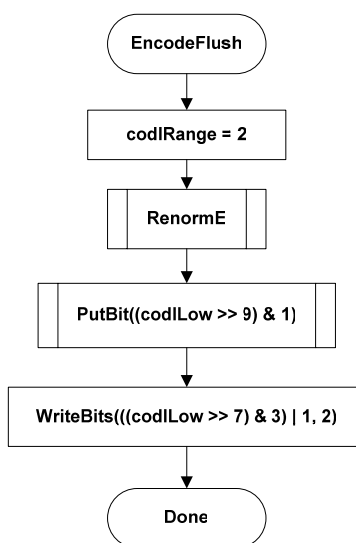


Figure 9-12 – Flowchart of flushing at termination

9.3.4.6 Byte stuffing process (informative)

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

This process is invoked after encoding the last macroblock of the last slice 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 macroblocks PicSizeInMbs in the picture, and the number of binary symbols BinCountsInNALunits resulting from encoding the contents of all VCL NAL units of the picture.

Outputs of this process are zero or more bytes appended to the NAL unit.

Let the variable k be set equal to $\text{Ceil}(\text{Ceil}(3 * (32 * \text{BinCountsInNALunits} - \text{RawMbBits} * \text{PicSizeInMbs}) \div 1024) - \text{NumBytesInVclNALunits}) \div 3$. Depending on the variable 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`.

Annex A

Profiles and levels

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

Profiles and levels specify restrictions on bitstreams and hence limits on the capabilities needed to decode the bitstreams. Profiles and levels may also be used to indicate interoperability points between individual decoder implementations.

NOTE 1 – This Recommendation | International Standard 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 specifies a set of limits on the values that may be taken by the syntax elements of this Recommendation | International Standard. The same set of level definitions is used with all profiles, but individual implementations may support a different level for each supported profile. For any given profile, levels generally correspond to decoder processing load and memory capability.

A.1 Requirements on video decoder capability

Capabilities of video decoders conforming to this Recommendation | International Standard are specified in terms of the ability to decode video streams conforming to the constraints of profiles and levels specified in this Annex. For each such profile, the level supported for that profile shall also be expressed.

Specific values are specified in this annex for the syntax elements `profile_idc` and `level_idc`. All other values of `profile_idc` and `level_idc` are reserved for future use by ITU-T | ISO/IEC.

NOTE – Decoders should not infer that when a reserved value of `profile_idc` or `level_idc` falls between the values specified in this Recommendation | International Standard that this indicates intermediate capabilities between the specified profiles or levels, as there are no restrictions on the method to be chosen by ITU-T | ISO/IEC for the use of such future reserved values.

A.2 Profiles

A.2.1 Baseline profile

Bitstreams conforming to the Baseline profile shall obey the following constraints:

- Only I and P slice types may be present.
- NAL unit streams shall not contain `nal_unit_type` values in the range of 2 to 4, inclusive.
- Sequence parameter sets shall have `frame_mbs_only_flag` equal to 1.
- The syntax elements `chroma_format_idc`, `bit_depth_luma_minus8`, `bit_depth_chroma_minus8`, `qpprime_y_zero_transform_bypass_flag`, and `seq_scaling_matrix_present_flag` shall not be present in sequence parameter sets.
- Picture parameter sets shall have `weighted_pred_flag` and `weighted_bipred_idc` both equal to 0.
- Picture parameter sets shall have `entropy_coding_mode_flag` equal to 0.
- Picture parameter sets shall have `num_slice_groups_minus1` in the range of 0 to 7, inclusive.
- The syntax elements `transform_8x8_mode_flag`, `pic_scaling_matrix_present_flag`, and `second_chroma_qp_index_offset` shall not be present in picture parameter sets.
- The syntax element `level_prefix` shall not be greater than 15.
- The level constraints specified for the Baseline profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the Baseline profile is specified by `profile_idc` being equal to 66.

Decoders conforming to the Baseline profile at a specific level shall be capable of decoding all bitstreams in which `profile_idc` is equal to 66 or `constraint_set0_flag` is equal to 1 and in which `level_idc` and `constraint_set3_flag` represent a level less than or equal to the specified level.

A.2.2 Main profile

Bitstreams conforming to the Main profile shall obey the following constraints:

- Only I, P, and B slice types may be present.
- NAL unit streams shall not contain `nal_unit_type` values in the range of 2 to 4, inclusive.
- Arbitrary slice order is not allowed.
- The syntax elements `chroma_format_idc`, `bit_depth_luma_minus8`, `bit_depth_chroma_minus8`, `qp_prime_y_zero_transform_bypass_flag`, and `seq_scaling_matrix_present_flag` shall not be present in sequence parameter sets.
- Picture parameter sets shall have `num_slice_groups_minus1` equal to 0 only.
- Picture parameter sets shall have `redundant_pic_cnt_present_flag` equal to 0 only.
- The syntax elements `transform_8x8_mode_flag`, `pic_scaling_matrix_present_flag`, and `second_chroma_qp_index_offset` shall not be present in picture parameter sets.
- The syntax element `level_prefix` shall not be greater than 15 (when present).
- The level constraints specified for the Main profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the Main profile is specified by `profile_idc` being equal to 77.

Decoders conforming to the Main profile at a specified level shall be capable of decoding all bitstreams in which `profile_idc` is equal to 77 or `constraint_set1_flag` is equal to 1 and in which `level_idc` and `constraint_set3_flag` represent a level less than or equal to the specified level.

A.2.3 Extended profile

Bitstreams conforming to the Extended profile shall obey the following constraints:

- Sequence parameter sets shall have `direct_8x8_inference_flag` equal to 1.
- The syntax elements `chroma_format_idc`, `bit_depth_luma_minus8`, `bit_depth_chroma_minus8`, `qp_prime_y_zero_transform_bypass_flag`, and `seq_scaling_matrix_present_flag` shall not be present in sequence parameter sets.
- Picture parameter sets shall have `entropy_coding_mode_flag` equal to 0.
- Picture parameter sets shall have `num_slice_groups_minus1` in the range of 0 to 7, inclusive.
- The syntax elements `transform_8x8_mode_flag`, `pic_scaling_matrix_present_flag`, and `second_chroma_qp_index_offset` shall not be present in picture parameter sets.
- The syntax element `level_prefix` shall not be greater than 15 (when present).
- The level constraints specified for the Extended profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the Extended profile is specified by `profile_idc` being equal to 88.

Decoders conforming to the Extended profile at a specified level shall be capable of decoding all bitstreams in which `profile_idc` is equal to 88 or `constraint_set2_flag` is equal to 1 and in which `level_idc` represents a level less than or equal to specified level.

Decoders conforming to the Extended profile at a specified level shall also be capable of decoding all bitstreams in which `profile_idc` is equal to 66 or `constraint_set0_flag` is equal to 1, in which `level_idc` and `constraint_set3_flag` represent a level less than or equal to the specified level.

A.2.4 High profile

Bitstreams conforming to the High profile shall obey the following constraints:

- Only I, P, and B slice types may be present.
- NAL unit streams shall not contain `nal_unit_type` values in the range of 2 to 4, inclusive.
- Arbitrary slice order is not allowed.
- Picture parameter sets shall have `num_slice_groups_minus1` equal to 0 only.
- Picture parameter sets shall have `redundant_pic_cnt_present_flag` equal to 0 only.
- Sequence parameter sets shall have `chroma_format_idc` in the range of 0 to 1 inclusive.
- Sequence parameter sets shall have `bit_depth_luma_minus8` equal to 0 only.
- Sequence parameter sets shall have `bit_depth_chroma_minus8` equal to 0 only.

- Sequence parameter sets shall have `qprime_y_zero_transform_bypass_flag` equal to 0 only.
- The level constraints specified for the High profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the High profile is specified by `profile_idc` being equal to 100. Decoders conforming to the High profile at a specific level shall be capable of decoding all bitstreams in which `level_idc` and `constraint_set3_flag` represents a level less than or equal to the specified level and either or both of the following conditions are true:

- `profile_idc` is equal to 77 or 100, or
- `constraint_set1_flag` is equal to 1.

A.2.5 High 10 profile

Bitstreams conforming to the High 10 profile shall obey the following constraints:

- Only I, P, and B slice types may be present.
- NAL unit streams shall not contain `nal_unit_type` values in the range of 2 to 4, inclusive.
- Arbitrary slice order is not allowed.
- Picture parameter sets shall have `num_slice_groups_minus1` equal to 0 only.
- Picture parameter sets shall have `redundant_pic_cnt_present_flag` equal to 0 only.
- Sequence parameter sets shall have `chroma_format_idc` in the range of 0 to 1 inclusive.
- Sequence parameter sets shall have `bit_depth_luma_minus8` in the range of 0 to 2 inclusive.
- Sequence parameter sets shall have `bit_depth_chroma_minus8` in the range of 0 to 2 inclusive.
- Sequence parameter sets shall have `qprime_y_zero_transform_bypass_flag` equal to 0 only.
- The level constraints specified for the High 10 profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the High 10 profile is specified by `profile_idc` being equal to 110. Decoders conforming to the High 10 profile at a specific level shall be capable of decoding all bitstreams in which `level_idc` and `constraint_set3_flag` represent a level less than or equal to the specified level and either or both of the following conditions are true:

- `profile_idc` is equal to 77, 100, or 110, or
- `constraint_set1_flag` is equal to 1.

A.2.6 High 4:2:2 profile

Bitstreams conforming to the High 4:2:2 profile shall obey the following constraints:

- Only I, P, and B slice types may be present.
- NAL unit streams shall not contain `nal_unit_type` values in the range of 2 to 4, inclusive.
- Arbitrary slice order is not allowed.
- Picture parameter sets shall have `num_slice_groups_minus1` equal to 0 only.
- Picture parameter sets shall have `redundant_pic_cnt_present_flag` equal to 0 only.
- Sequence parameter sets shall have `chroma_format_idc` in the range of 0 to 2 inclusive
- Sequence parameter sets shall have `bit_depth_luma_minus8` in the range of 0 to 2 inclusive.
- Sequence parameter sets shall have `bit_depth_chroma_minus8` in the range of 0 to 2 inclusive.
- Sequence parameter sets shall have `qprime_y_zero_transform_bypass_flag` equal to 0 only.
- The level constraints specified for the High 4:2:2 profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the High 4:2:2 profile is specified by `profile_idc` being equal to 122. Decoders conforming to the High 4:2:2 profile at a specific level shall be capable of decoding all bitstreams in which `level_idc` and `constraint_set3_flag` represents a level less than or equal to the specified level and either or both of the following conditions are true:

- `profile_idc` is equal to 77, 100, 110, or 122, or
- `constraint_set1_flag` is equal to 1.

A.2.7 High 4:4:4 profile

Bitstreams conforming to the High 4:4:4 profile shall obey the following constraints:

- Only I, P, and B slice types may be present.
- NAL unit streams shall not contain nal_unit_type values in the range of 2 to 4, inclusive.
- Arbitrary slice order is not allowed.
- Picture parameter sets shall have num_slice_groups_minus1 equal to 0 only.
- Picture parameter sets shall have redundant_pic_cnt_present_flag equal to 0 only.
- Sequence parameter sets shall have bit_depth_luma_minus8 in the range of 0 to 4 inclusive.
- Sequence parameter sets shall have bit_depth_chroma_minus8 in the range of 0 to 4 inclusive.
- The level constraints specified for the High 4:4:4 profile in subclause A.3 shall be fulfilled.

Conformance of a bitstream to the High 4:4:4 profile is specified by profile_idc being equal to 144. Decoders conforming to the High 4:4:4 profile at a specific level shall be capable of decoding all bitstreams in which level_idc and constraint_set3_flag represent a level less than or equal to the specified level and either or both of the following conditions are true:

- profile_idc is equal to 77, 100, 110, 122, or 144, or
- constraint_set1_flag is equal to 1.

A.3 Levels

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.
- Let picture n be the primary coded picture or the corresponding decoded picture of access unit n.

A.3.1 Level limits common to the Baseline, Main, and Extended profiles

Let the variable fR be derived as follows.

- If picture n is a frame, fR is set equal to $1 \div 172$.
- Otherwise (picture n is a field), fR is set equal to $1 \div (172 * 2)$.

Bitstreams conforming to the Baseline, Main, or Extended profiles at a specified level shall obey the following constraints:

- a) The nominal removal time of access unit n (with $n > 0$) from the CPB as specified in subclause C.1.2, satisfies the constraint that $t_{r,n}(n) - t_r(n - 1)$ is greater than or equal to $\text{Max}(\text{PicSizeInMbs} \div \text{MaxMBPS}, \text{fR})$, where MaxMBPS is the value specified in Table A-1 that applies to picture n - 1, and PicSizeInMbs is the number of macroblocks in picture n - 1.
- b) The difference between consecutive output times of pictures from the DPB as specified in subclause C.2.2, satisfies the constraint that $\Delta t_{o,dpb}(n) \geq \text{Max}(\text{PicSizeInMbs} \div \text{MaxMBPS}, \text{fR})$, where MaxMBPS is the value specified in Table A-1 for picture n, and PicSizeInMbs is the number of macroblocks of 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 sum of the NumBytesInNALunit variables for access unit 0 is less than or equal to $384 * (\text{PicSizeInMbs} + \text{MaxMBPS} * (t_r(0) - t_{r,n}(0))) \div \text{MinCR}$, where MaxMBPS and MinCR are the values specified in Table A-1 that apply to picture 0 and PicSizeInMbs is the number of macroblocks in picture 0.
- d) The sum of the NumBytesInNALunit variables for access unit n (with $n > 0$) is less than or equal to $384 * \text{MaxMBPS} * (t_r(n) - t_r(n - 1)) \div \text{MinCR}$, where MaxMBPS and MinCR are the values specified in Table A-1 that apply to picture n.
- e) $\text{PicWidthInMbs} * \text{FrameHeightInMbs} \leq \text{MaxFS}$, where MaxFS is specified in Table A-1
- f) $\text{PicWidthInMbs} \leq \text{Sqrt}(\text{MaxFS} * 8)$
- g) $\text{FrameHeightInMbs} \leq \text{Sqrt}(\text{MaxFS} * 8)$
- h) $\text{max_dec_frame_buffering} \leq \text{MaxDpbSize}$, where MaxDpbSize is equal to $\text{Min}(1024 * \text{MaxDPB} / (\text{PicWidthInMbs} * \text{FrameHeightInMbs} * 384), 16)$ and MaxDPB is given in Table A-1 in units of 1024 bytes.

- i) For the VCL HRD parameters, $\text{BitRate}[\text{SchedSelIdx}] \leq 1000 * \text{MaxBR}$ and $\text{CpbSize}[\text{SchedSelIdx}] \leq 1000 * \text{MaxCPB}$ for at least one value of SchedSelIdx, where $\text{BitRate}[\text{SchedSelIdx}]$ is given by Equation E-37 and $\text{CpbSize}[\text{SchedSelIdx}]$ is given by Equation E-38 when `vcl_hrd_parameters_present_flag` is equal to 1. MaxBR and MaxCPB are specified in Table A-1 in units of 1000 bits/s and 1000 bits, respectively. The bitstream shall satisfy these conditions for at least one value of SchedSelIdx in the range 0 to `cpb_cnt_minus1`, inclusive.
- j) For the NAL HRD parameters, $\text{BitRate}[\text{SchedSelIdx}] \leq 1200 * \text{MaxBR}$ and $\text{CpbSize}[\text{SchedSelIdx}] \leq 1200 * \text{MaxCPB}$ for at least one value of SchedSelIdx, where $\text{BitRate}[\text{SchedSelIdx}]$ is given by Equation E-37 and $\text{CpbSize}[\text{SchedSelIdx}]$ is given by Equation E-38 when `nal_hrd_parameters_present_flag` equal to 1. MaxBR and MaxCPB are specified in Table A-1 in units of 1200 bits/s and 1200 bits, respectively. The bitstream shall satisfy these conditions for at least one value of SchedSelIdx in the range 0 to `cpb_cnt_minus1`.
- k) Vertical motion vector component range luma motion vectors does not exceed MaxVmvR in units of luma frame samples, where MaxVmvR is specified in Table A-1
 - NOTE 1 – When `chroma_format_idc` is equal to 1 and the current macroblock is a field macroblock, the motion vector component range for chroma motion vectors may exceed MaxVmvR in units of luma frame samples, due to the method of deriving chroma motion vectors as specified in subclause 8.4.1.4.
- l) Horizontal motion vector range does not exceed the range of -2048 to 2047.75, inclusive, in units of luma samples
- m) Number of motion vectors per two consecutive macroblocks in decoding order (also applying to the total from the last macroblock of a slice and the first macroblock of the next slice in decoding order, and in particular also applying to the total from the last macroblock of the last slice of a picture and the first macroblock of the first slice of the next picture in decoding order) does not exceed MaxMvsPer2Mb, where MaxMvsPer2Mb is specified in Table A-1. The number of motion vectors for each macroblock is the value of the variable MvCnt after the completion of the intra or inter prediction process for the macroblock.
- n) Number of bits of `macroblock_layer()` data for any macroblock is not greater than 3200. Depending on `entropy_coding_mode_flag`, the bits of `macroblock_layer()` data are counted as follows.
 - If `entropy_coding_mode_flag` is equal to 0, the number of bits of `macroblock_layer()` data is given by the number of bits in the `macroblock_layer()` syntax structure for a macroblock.
 - Otherwise (`entropy_coding_mode_flag` is equal to 1), the number of bits of `macroblock_layer()` data for a macroblock is given by the number of times `read_bits(1)` is called in subclauses 9.3.3.2.2 and 9.3.3.2.3 when parsing the `macroblock_layer()` associated with the macroblock.

Table A-1 specifies the limits for each level. Entries marked "-" in Table A-1 denote the absence of a corresponding limit. For purposes of comparison of level capabilities, a level shall be considered to be a lower (higher) level than some other level if the level appears nearer to the top (bottom) row of Table A-1 than the other level.

A level to which the bitstream conforms shall be indicated by the syntax elements `level_idc` and `constraint_set3_flag` as follows.

- If `level_idc` is equal to 11 and `constraint_set3_flag` is equal to 1, the indicated level is level 1b.
- Otherwise (`level_idc` is not equal to 11 or `constraint_set3_flag` is not equal to 1), `level_idc` shall be set equal to a value of ten times the level number specified in Table A-1 and `constraint_set3_flag` shall be set equal to 0.

Table A-1 – Level limits

Level number	Max macroblock processing rate MaxMBPS (MB/s)	Max frame size MaxFS (MBs)	Max decoded picture buffer size MaxDPB (1024 bytes for 4:2:0)	Max video bit rate MaxBR (1000 bits/s, 1200 bits/s, cpbBrVclFactor bits/s, or cpbBrNalFactor bits/s)	Max CPB size MaxCPB (1000 bits, 1200 bits, cpbBrVclFactor bits, or cpbBrNalFactor bits)	Vertical MV component range MaxVmvR (luma frame samples)	Min compression ratio MinCR	Max number of motion vectors per two consecutive MBs MaxMvsPer2Mb
1	1 485	99	148.5	64	175	[-64,+63.75]	2	-
1b	1 485	99	148.5	128	350	[-64,+63.75]	2	-
1.1	3 000	396	337.5	192	500	[-128,+127.75]	2	-
1.2	6 000	396	891.0	384	1 000	[-128,+127.75]	2	-
1.3	11 880	396	891.0	768	2 000	[-128,+127.75]	2	-
2	11 880	396	891.0	2 000	2 000	[-128,+127.75]	2	-
2.1	19 800	792	1 782.0	4 000	4 000	[-256,+255.75]	2	-
2.2	20 250	1 620	3 037.5	4 000	4 000	[-256,+255.75]	2	-
3	40 500	1 620	3 037.5	10 000	10 000	[-256,+255.75]	2	32
3.1	108 000	3 600	6 750.0	14 000	14 000	[-512,+511.75]	4	16
3.2	216 000	5 120	7 680.0	20 000	20 000	[-512,+511.75]	4	16
4	245 760	8 192	12 288.0	20 000	25 000	[-512,+511.75]	4	16
4.1	245 760	8 192	12 288.0	50 000	62 500	[-512,+511.75]	2	16
4.2	522 240	8 704	13 056.0	50 000	62 500	[-512,+511.75]	2	16
5	589 824	22 080	41 400.0	135 000	135 000	[-512,+511.75]	2	16
5.1	983 040	36 864	69 120.0	240 000	240 000	[-512,+511.75]	2	16

Levels with non-integer level numbers in Table A-1 are referred to as “intermediate levels”.

NOTE 2 – All levels have the same status, but some applications may choose to use only the integer-numbered levels.

Informative subclause A.3.4 shows the effect of these limits on frame rates for several example picture formats.

A.3.2 Level limits common to the High, High 10, High 4:2:2, and High 4:4:4 profiles

Let the variable fR be derived as follows.

- If picture n is a frame, fR is set equal to $1 \div 172$.
- Otherwise (picture n is a field), fR is set equal to $1 \div (172 * 2)$.

Bitstreams conforming to the High, High 10, High 4:2:2, or High 4:4:4 profiles at a specified level shall obey the following constraints:

- a) The nominal removal time of access unit n (with $n > 0$) from the CPB as specified in subclause C.1.2, satisfies the constraint that $t_{r,n}(n) - t_r(n-1)$ is greater than or equal to $\text{Max}(\text{PicSizeInMbs} \div \text{MaxMBPS}, fR)$, where MaxMBPS is the value specified in Table A-1 that applies to picture $n-1$, and PicSizeInMbs is the number of macroblocks in picture $n-1$.
- b) The difference between consecutive output times of pictures from the DPB as specified in subclause C.2.2, satisfies the constraint that $\Delta t_{o,dpb}(n) \geq \text{Max}(\text{PicSizeInMbs} \div \text{MaxMBPS}, fR)$, where MaxMBPS is the value specified in Table A-1 for picture n , and PicSizeInMbs is the number of macroblocks of 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) $\text{PicWidthInMbs} * \text{FrameHeightInMbs} \leq \text{MaxFS}$, where MaxFS is specified in Table A-1

- d) $\text{PicWidthInMbs} \leq \text{Sqrt}(\text{MaxFS} * 8)$
- e) $\text{FrameHeightInMbs} \leq \text{Sqrt}(\text{MaxFS} * 8)$
- f) $\text{max_dec_frame_buffering} \leq \text{MaxDpbSize}$, where MaxDpbSize is equal to $\text{Min}(1024 * \text{MaxDPB} / (\text{PicWidthInMbs} * \text{FrameHeightInMbs} * 384), 16)$ and MaxDPB is specified in Table A-1.
- g) Vertical motion vector component range does not exceed MaxVmvR in units of luma frame samples, where MaxVmvR is specified in Table A-1.
- h) Horizontal motion vector range does not exceed the range of -2048 to 2047.75, inclusive, in units of luma samples.
- i) Number of motion vectors per two consecutive macroblocks in decoding order (also applying to the total from the last macroblock of a slice and the first macroblock of the next slice in decoding order) does not exceed MaxMvsPer2Mb , where MaxMvsPer2Mb is specified in Table A-1. The number of motion vectors for each macroblock is value of the variable MvCnt after the completion of the intra or inter prediction process for the macroblock.
- j) Number of bits of $\text{macroblock_layer}()$ data for any macroblock is not greater than $128 + \text{RawMbBits}$. Depending on $\text{entropy_coding_mode_flag}$, the bits of $\text{macroblock_layer}()$ data are counted as follows.
 - If $\text{entropy_coding_mode_flag}$ is equal to 0, the number of bits of $\text{macroblock_layer}()$ data is given by the number of bits in the $\text{macroblock_layer}()$ syntax structure for a macroblock.
 - Otherwise ($\text{entropy_coding_mode_flag}$ is equal to 1), the number of bits of $\text{macroblock_layer}()$ data for a macroblock is given by the number of times $\text{read_bits}(1)$ is called in subclauses 9.3.3.2.2 and 9.3.3.2.3 when parsing the $\text{macroblock_layer}()$ associated with the macroblock.

Table A-1 specifies the limits for each level. Entries marked "-" in Table A-1 denote the absence of a corresponding limit.

A level to which the bitstream conforms shall be indicated by the syntax element level_idc as follows.

- If level_idc is equal to 9, the indicated level is level 1b.
- Otherwise (level_idc is not equal to 9), level_idc shall be set equal to a value of ten times the level number specified in Table A-1.

A.3.3 Profile-specific level limits

- a) In bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 profiles, the removal time of access unit 0 shall satisfy the constraint that the number of slices in picture 0 is less than or equal to $(\text{PicSizeInMbs} + \text{MaxMBPS} * (\text{t}_r(0) - \text{t}_{r,n}(0))) \div \text{SliceRate}$, where SliceRate is the value specified in Table A-4 that applies to picture 0.
- b) In bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 profiles, the difference between consecutive removal time of access units n and $n - 1$ (with $n > 0$) shall satisfy the constraint that the number of slices in picture n is less than or equal to $\text{MaxMBPS} * (\text{t}_r(n) - \text{t}_r(n - 1)) \div \text{SliceRate}$, where SliceRate is the value specified in Table A-4 that applies to picture n .
- c) In bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 profiles, sequence parameter sets shall have $\text{direct_8x8_inference_flag}$ equal to 1 for the levels specified in Table A-4.
NOTE 1 – $\text{direct_8x8_inference_flag}$ is not relevant to the Baseline profile as it does not allow B slice types (specified in subclause A.2.1), and $\text{direct_8x8_inference_flag}$ is equal to 1 for all levels of the Extended profile (specified in subclause A.2.3).
- d) In bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 or Extended profiles, sequence parameter sets shall have $\text{frame_mbs_only_flag}$ equal to 1 for the levels specified in Table A-4 for the Main, High, High 10, High 4:2:2, and High 4:4:4 profiles and in Table A-5 for the Extended profile.
NOTE 2 – $\text{frame_mbs_only_flag}$ is equal to 1 for all levels of the Baseline profile (specified in subclause A.2.1).
- e) In bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 or Extended profiles, the value of sub_mb_type in B macroblocks shall not be equal to B_Bi_8x4 , B_Bi_4x8 , or B_Bi_4x4 for the levels in which MinLumaBiPredSize is shown as 8x8 in Table A-4 for the Main, High, High 10, High 4:2:2, and High 4:4:4 profiles and in Table A-5 for the Extended profile.
- f) In bitstreams conforming to the Baseline and Extended profiles, $(\text{xInt}_{\text{max}} - \text{xInt}_{\text{min}} + 6) * (\text{yInt}_{\text{max}} - \text{yInt}_{\text{min}} + 6) \leq \text{MaxSubMbRectSize}$ in macroblocks coded with mb_type equal to P_8x8 , P_8x8ref0 or B_8x8 for all

invocations of the process specified in subclause 8.4.2.2.1 used to generate the predicted luma sample array for a single reference picture list (reference picture list 0 or reference picture list 1) for each 8x8 sub-macroblock, where $\text{NumSubMbPart}(\text{sub_mb_type}) > 1$, where MaxSubMbRectSize is specified in Table A-3 for the Baseline profile and in Table A-5 for the Extended profile and

- $x\text{Int}_{\min}$ is the minimum value of $x\text{Int}_L$ among all luma sample predictions for the sub-macroblock
 - $x\text{Int}_{\max}$ is the maximum value of $x\text{Int}_L$ among all luma sample predictions for the sub-macroblock
 - $y\text{Int}_{\min}$ is the minimum value of $y\text{Int}_L$ among all luma sample predictions for the sub-macroblock
 - $y\text{Int}_{\max}$ is the maximum value of $y\text{Int}_L$ among all luma sample predictions for the sub-macroblock
- g) In bitstreams conforming to the High, High 10, High 4:2:2, or High 4:4:4 profile, for the VCL HRD parameters, $\text{BitRate}[\text{SchedSelIdx}] \leq \text{cpbBrVclFactor} * \text{MaxBR}$ and $\text{CpbSize}[\text{SchedSelIdx}] \leq \text{cpbBrVclFactor} * \text{MaxCPB}$ for at least one value of SchedSelIdx , where cpbBrVclFactor is specified in Table A-2, $\text{BitRate}[\text{SchedSelIdx}]$ is specified by Equation E-37 and $\text{CpbSize}[\text{SchedSelIdx}]$ is specified by Equation E-38 when $\text{vcl_hrd_parameters_present_flag}$ is equal to 1. MaxBR and MaxCPB are specified in Table A-1 in units of cpbBrVclFactor bits/s and cpbBrVclFactor bits, respectively. The bitstream shall satisfy these conditions for at least one value of SchedSelIdx in the range 0 to cpb_cnt_minus1 , inclusive.
- h) In bitstreams conforming to the High, High 10, High 4:2:2, or High 4:4:4 profile, for the NAL HRD parameters, $\text{BitRate}[\text{SchedSelIdx}] \leq \text{cpbBrNalFactor} * \text{MaxBR}$ and $\text{CpbSize}[\text{SchedSelIdx}] \leq \text{cpbBrNalFactor} * \text{MaxCPB}$ for at least one value of SchedSelIdx , where cpbBrNalFactor is specified in Table A-2, $\text{BitRate}[\text{SchedSelIdx}]$ is specified by Equation E-37 and $\text{CpbSize}[\text{SchedSelIdx}]$ is specified by Equation E-38 when $\text{nal_hrd_parameters_present_flag}$ equal to 1. MaxBR and MaxCPB are specified in Table A-1 in units of cpbBrNalFactor bits/s and cpbBrNalFactor bits, respectively. The bitstream shall satisfy these conditions for at least one value of SchedSelIdx in the range 0 to cpb_cnt_minus1 .

Table A-2 – Specification of cpbBrVclFactor and cpbBrNalFactor

Profile	cpbBrVclFactor	cpbBrNalFactor
High	1 250	1 500
High 10	3 000	3 600
High 4:2:2	4 000	4 800
High 4:4:4	4 000	4 800

A.3.3.1 Baseline profile limits

Table A-3 specifies limits for each level that are specific to bitstreams conforming to the Baseline profile. Entries marked "-" in Table A-3 denote the absence of a corresponding limit.

Table A-3 – Baseline profile level limits

Level number	MaxSubMbRectSize
1	576
1b	576
1.1	576
1.2	576
1.3	576
2	576
2.1	576
2.2	576
3	576
3.1	-
3.2	-
4	-
4.1	-
4.2	-
5	-
5.1	-

A.3.3.2 Main, High, High 10, High 4:2:2, or High 4:4:4 profile limits

Table A-4 specifies limits for each level that are specific to bitstreams conforming to the Main, High, High 10, High 4:2:2, or High 4:4:4 profiles. Entries marked "-" in Table A-4 denote the absence of a corresponding limit.

Table A-4 – Main, High, High 10, High 4:2:2, or High 4:4:4 profile level limits

Level number	SliceRate	MinLumaBiPredSize	direct_8x8_inference_flag	frame_mbs_only_flag
1	-	-	-	1
1b	-	-	-	1
1.1	-	-	-	1
1.2	-	-	-	1
1.3	-	-	-	1
2	-	-	-	1
2.1	-	-	-	-
2.2	-	-	-	-
3	22	-	1	-
3.1	60	8x8	1	-
3.2	60	8x8	1	-
4	60	8x8	1	-
4.1	24	8x8	1	-
4.2	24	8x8	1	1
5	24	8x8	1	1
5.1	24	8x8	1	1

A.3.3.3 Extended Profile Limits

Table A-5 specifies limits for each level that are specific to bitstreams conforming to the Extended profile. Entries marked "-" in Table A-5 denote the absence of a corresponding limit.

Table A-5 – Extended profile level limits

Level number	MaxSubMbRectSize	MinLumaBiPredSize	frame_mbs_only_flag
1	576	-	1
1b	576	-	1
1.1	576	-	1
1.2	576	-	1
1.3	576	-	1
2	576	-	1
2.1	576	-	-
2.2	576	-	-
3	576	-	-
3.1	-	8x8	-
3.2	-	8x8	-
4	-	8x8	-
4.1	-	8x8	-
4.2	-	8x8	1
5	-	8x8	1
5.1	-	8x8	1

A.3.4 Effect of level limits on frame rate (informative)

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

Table A-6 – Maximum frame rates (frames per second) for some example frame sizes

Level:					1	1b	1.1	1.2	1.3	2	2.1
Max frame size (macroblocks):					99	99	396	396	396	396	792
Max macroblocks/second:					1 485	1 485	3 000	6 000	11 880	11 880	19 800
Max frame size (samples):					25 344	25 344	101 376	101 376	101 376	101 376	202 752
Max samples/second:					380 160	380 160	768 000	1 536 000	3 041 280	3 041 280	5 068 800
Format	Luma Width	Luma Height	MBs Total	Luma Samples							
SQCIF	128	96	48	12 288	30.9	30.9	62.5	125.0	172.0	172.0	172.0
QCIF	176	144	99	25 344	15.0	15.0	30.3	60.6	120.0	120.0	172.0
QVGA	320	240	300	76 800	-	-	10.0	20.0	39.6	39.6	66.0
525 SIF	352	240	330	84 480	-	-	9.1	18.2	36.0	36.0	60.0
CIF	352	288	396	101 376	-	-	7.6	15.2	30.0	30.0	50.0
525 HHR	352	480	660	168 960	-	-	-	-	-	-	30.0
625 HHR	352	576	792	202 752	-	-	-	-	-	-	25.0
VGA	640	480	1 200	307 200	-	-	-	-	-	-	-
525 4SIF	704	480	1 320	337 920	-	-	-	-	-	-	-
525 SD	720	480	1 350	345 600	-	-	-	-	-	-	-
4CIF	704	576	1 584	405 504	-	-	-	-	-	-	-
625 SD	720	576	1 620	414 720	-	-	-	-	-	-	-
SVGA	800	600	1 900	486 400	-	-	-	-	-	-	-
XGA	1024	768	3 072	786 432	-	-	-	-	-	-	-
720p HD	1280	720	3 600	921 600	-	-	-	-	-	-	-
4VGA	1280	960	4 800	1 228 800	-	-	-	-	-	-	-
SXGA	1280	1024	5 120	1 310 720	-	-	-	-	-	-	-
525 16SIF	1408	960	5 280	1 351 680	-	-	-	-	-	-	-
16CIF	1408	1152	6 336	1 622 016	-	-	-	-	-	-	-
4SVGA	1600	1200	7 500	1 920 000	-	-	-	-	-	-	-
1080 HD	1920	1088	8 160	2 088 960	-	-	-	-	-	-	-
2Kx1K	2048	1024	8 192	2 097 152	-	-	-	-	-	-	-
2Kx1080	2048	1088	8 704	2 228 224	-	-	-	-	-	-	-
4XGA	2048	1536	12 288	3 145 728	-	-	-	-	-	-	-
16VGA	2560	1920	19 200	4 915 200	-	-	-	-	-	-	-
3616x1536 (2.35:1)	3616	1536	21 696	5 554 176	-	-	-	-	-	-	-
3672x1536 (2.39:1)	3680	1536	22 080	5 652 480	-	-	-	-	-	-	-
4Kx2K	4096	2048	32 768	8 388 608	-	-	-	-	-	-	-
4096x2304 (16:9)	4096	2304	36 864	9 437 184	-	-	-	-	-	-	-

Table A-6 (continued) – Maximum frame rates (frames per second) for some example frame sizes

Level:					2.2	3	3.1	3.2	4	4.1	4.2
Max frame size (macroblocks):					1 620	1 620	3 600	5 120	8 192	8 192	8 704
Max macroblocks/second:					20 250	40 500	108 000	216 000	245 760	245 760	522 240
Max frame size (samples):					414 720	414 720	921 600	1 310 720	2 097 152	2 097 152	2 228 224
Max samples/second:					5 184 000	10 368 000	27 648 000	55 296 000	62 914 560	62 914 560	133 693 440
Format	Luma Width	Luma Height	MBs Total	Luma Samples							
SQCIF	128	96	48	12 288	172.0	172.0	172.0	172.0	172.0	172.0	172.0
QCIF	176	144	99	25 344	172.0	172.0	172.0	172.0	172.0	172.0	172.0
QVGA	320	240	300	76 800	67.5	135.0	172.0	172.0	172.0	172.0	172.0
525 SIF	352	240	330	84 480	61.4	122.7	172.0	172.0	172.0	172.0	172.0
CIF	352	288	396	101 376	51.1	102.3	172.0	172.0	172.0	172.0	172.0
525 HHR	352	480	660	168 960	30.7	61.4	163.6	172.0	172.0	172.0	172.0
625 HHR	352	576	792	202 752	25.6	51.1	136.4	172.0	172.0	172.0	172.0
VGA	640	480	1 200	307 200	16.9	33.8	90.0	172.0	172.0	172.0	172.0
525 4SIF	704	480	1 320	337 920	15.3	30.7	81.8	163.6	172.0	172.0	172.0
525 SD	720	480	1 350	345 600	15.0	30.0	80.0	160.0	172.0	172.0	172.0
4CIF	704	576	1 584	405 504	12.8	25.6	68.2	136.4	155.2	155.2	172.0
625 SD	720	576	1 620	414 720	12.5	25.0	66.7	133.3	151.7	151.7	172.0
SVGA	800	600	1 900	486 400	-	-	56.8	113.7	129.3	129.3	172.0
XGA	1024	768	3 072	786 432	-	-	35.2	70.3	80.0	80.0	172.0
720p HD	1280	720	3 600	921 600	-	-	30.0	60.0	68.3	68.3	145.1
4VGA	1280	960	4 800	1 228 800	-	-	-	45.0	51.2	51.2	108.8
SXGA	1280	1024	5 120	1 310 720	-	-	-	42.2	48.0	48.0	102.0
525 16SIF	1408	960	5 280	1 351 680	-	-	-	-	46.5	46.5	98.9
16CIF	1408	1152	6 336	1 622 016	-	-	-	-	38.8	38.8	82.4
4SVGA	1600	1200	7 500	1 920 000	-	-	-	-	32.8	32.8	69.6
1080 HD	1920	1088	8 160	2 088 960	-	-	-	-	30.1	30.1	64.0
2Kx1K	2048	1024	8 192	2 097 152	-	-	-	-	30.0	30.0	63.8
2Kx1080	2048	1088	8 704	2 228 224	-	-	-	-	-	-	60.0
4XGA	2048	1536	12 288	3 145 728	-	-	-	-	-	-	-
16VGA	2560	1920	19 200	4 915 200	-	-	-	-	-	-	-
3616x1536 (2.35:1)	3616	1536	21 696	5 554 176	-	-	-	-	-	-	-
3672x1536 (2.39:1)	3680	1536	22 080	5 652 480	-	-	-	-	-	-	-
4Kx2K	4096	2048	32 768	8 388 608	-	-	-	-	-	-	-
4096x2304 (16:9)	4096	2304	36 864	9 437 184	-	-	-	-	-	-	-

Table A-6 (concluded) – Maximum frame rates (frames per second) for some example frame sizes

Level:					5	5.1
Max frame size (macroblocks):					22 080	36 864
Max macroblocks/second:					589 824	983 040
Max frame size (samples):					5 652 480	9 437 184
Max samples/second:					150 994 944	251 658 240
Format	Luma Width	Luma Height	MBs Total	Luma Samples		
SQCIF	128	96	48	12 288	172.0	172.0
QCIF	176	144	99	25 344	172.0	172.0
QVGA	320	240	300	76 800	172.0	172.0
525 SIF	352	240	330	84 480	172.0	172.0
CIF	352	288	396	101 376	172.0	172.0
525 HHR	352	480	660	168 960	172.0	172.0
625 HHR	352	576	792	202 752	172.0	172.0
VGA	640	480	1 200	307 200	172.0	172.0
525 4SIF	704	480	1 320	337 920	172.0	172.0
525 SD	720	480	1 350	345 600	172.0	172.0
4CIF	704	576	1 584	405 504	172.0	172.0
625 SD	720	576	1 620	414 720	172.0	172.0
SVGA	800	600	1 900	486 400	172.0	172.0
XGA	1024	768	3 072	786 432	172.0	172.0
720p HD	1280	720	3 600	921 600	163.8	172.0
4VGA	1280	960	4 800	1 228 800	122.9	172.0
SXGA	1280	1024	5 120	1 310 720	115.2	172.0
525 16SIF	1408	960	5 280	1 351 680	111.7	172.0
16CIF	1408	1152	6 336	1 622 016	93.1	155.2
4SVGA	1600	1200	7 500	1 920 000	78.6	131.1
1080 HD	1920	1088	8 160	2 088 960	72.3	120.5
2Kx1K	2048	1024	8 192	2 097 152	72.0	120.0
2Kx1080	2048	1088	8 704	2 228 224	67.8	112.9
4XGA	2048	1536	12 288	3 145 728	48.0	80.0
16VGA	2560	1920	19 200	4 915 200	30.7	51.2
3616x1536 (2.35:1)	3616	1536	21 696	5 554 176	27.2	45.3
3672x1536 (2.39:1)	3680	1536	22 080	5 652 480	26.7	44.5
4Kx2K	4096	2048	32 768	8 388 608	-	30.0
4096x2304 (16:9)	4096	2304	36 864	9 437 184	-	26.7

The following should be noted.

- This Recommendation | International Standard is a variable-frame-size specification. The specific frame sizes in Table A-6 are illustrative examples only.
- As used in Table A-6, "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.
- Frame rates given are correct for progressive scan modes. The frame rates are also correct for interlaced video coding for the cases of frame height divisible by 32.

Annex B

Byte stream format

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

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 ITU-T Rec. H.222.0 | ISO/IEC 13818-1 systems or ITU-T Rec. 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.1 Byte stream NAL unit syntax and semantics

B.1.1 Byte stream NAL unit syntax

	C	Descriptor
byte_stream_nal_unit(NumBytesInNALunit) {		
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.1.2 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 7.4.1.2). 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 7.4.1.2.3).

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.1.1) 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 any of the following conditions are fulfilled, the zero_byte syntax element shall be present.

- the nal_unit_type within the nal_unit() is equal to 7 (sequence parameter set) or 8 (picture parameter set)
- the byte stream NAL unit syntax structure contains the first NAL unit of an access unit in decoding order, as specified by subclause 7.4.1.2.3.

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.2 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 initialises 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 (if 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 any of the following conditions:
 - a. A subsequent byte-aligned three-byte sequence equal to 0x000000, or
 - b. A subsequent byte-aligned three-byte sequence equal to 0x000001, or
 - c. 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.3 Decoder byte-alignment recovery (informative)

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

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 is able to determine whether or not the positions of data in the bitstream are byte-aligned. When a decoder does not have byte alignment with the encoder's byte stream, 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 encoder and positioned at the start of a NAL unit in the byte stream.

Once byte aligned with the encoder, the decoder can examine the incoming byte stream 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 7.4.1.

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 7.4.1), 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 in this subclause.

Annex C Hypothetical reference decoder

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

This annex specifies the hypothetical reference decoder (HRD) and its use to check bitstream and decoder conformance.

Two types of bitstreams are subject to HRD conformance checking for this Recommendation | International Standard. The first such type of bitstream, called Type I bitstream, is a NAL unit stream containing only the VCL NAL units and filler data NAL units for all access units in the bitstream. The second type of bitstream, 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.

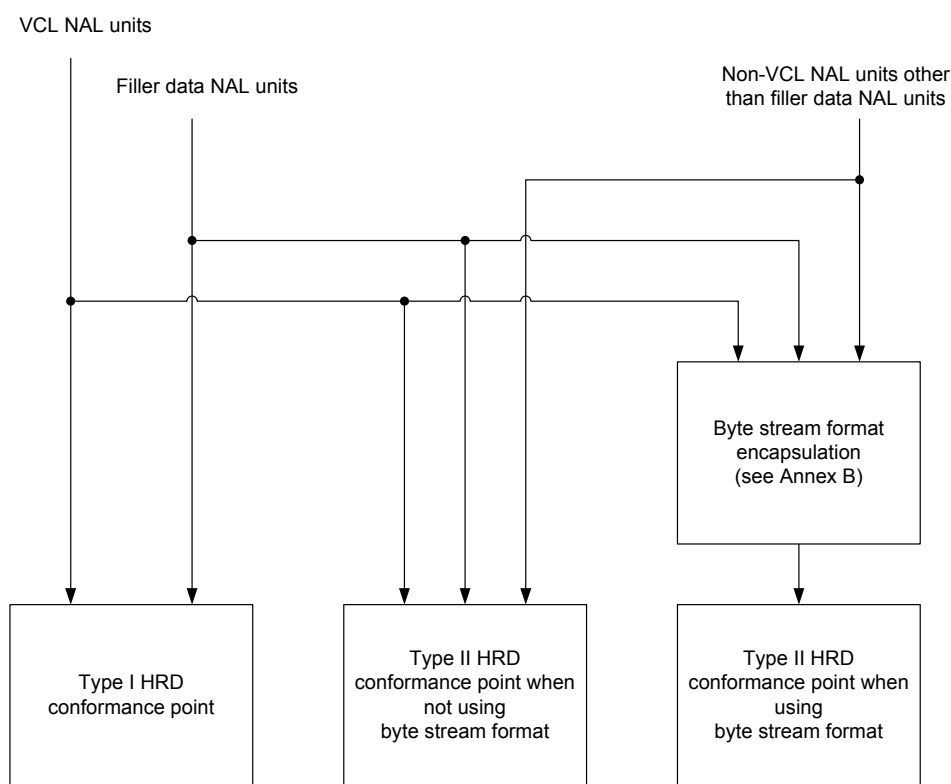


Figure C-1 – Structure of byte streams and NAL unit streams for HRD conformance checks

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 and Annexes D and E.

Two types of HRD parameter sets are used. The HRD parameter sets are signalled through video usability information as specified in subclauses E.1 and E.2, which is part of the sequence parameters set syntax structure.

In order to check conformance of a bitstream using the HRD, all sequence parameter sets and picture parameters sets referred to in the VCL NAL units, and corresponding buffering period and picture timing 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 Recommendation | International Standard.

In Annexes C, D and E, the specification for "presence" of non-VCL NAL units 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 by this

Recommendation | International Standard. For the purpose of counting bits, only the appropriate bits that are actually present in the bitstream are counted.

NOTE 1 – As an example, synchronization of 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 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 specified in this annex.

NOTE 2 – 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 is supplied by some other means not specified in this Recommendation | International Standard.

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.

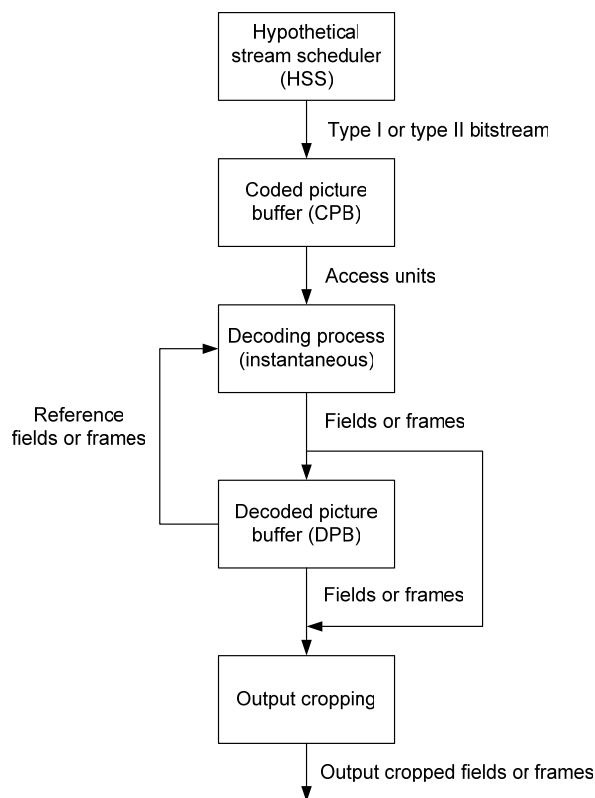


Figure C-2 – HRD buffer model

The CPB size (number of bits) is $CpbSize[SchedSelIdx]$. The DPB size (number of frame buffers) is $Max(1, max_dec_frame_buffering)$.

The HRD operates as follows. Data associated with access units that flow into the CPB according to a specified arrival schedule are delivered by the HSS. The data associated with each access unit are removed and decoded instantaneously by the instantaneous decoding process at CPB removal times. Each decoded picture is placed in the DPB at its CPB removal time unless it is output at its CPB removal time and is a non-reference picture. When a picture is placed in the DPB it is removed from the DPB at the later of the DPB output time or the time that it is marked as "unused for reference".

The operation of the CPB is specified in subclause C.1. The instantaneous decoder operation is specified in clauses 8 and 9. The operation of the DPB is specified in subclause C.2. The output cropping is specified in subclause C.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.1.1, E.1.2, E.2.1 and E.2.2. The HRD is initialised as specified by the buffering period SEI message as specified in subclauses D.1.1 and D.2.1. The removal timing of access units from the CPB and output timing from the DPB are specified in the picture timing SEI message as specified in subclauses D.1.2 and D.2.2. All timing information relating to a specific access unit shall arrive prior to the CPB removal time of the access unit.

The HRD is used to check conformance of bitstreams and decoders as specified in subclauses C.3 and C.4, respectively.

NOTE 3 – While conformance is guaranteed under the assumption that all frame-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 done 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 an access unit is not necessarily an integer.

The variable t_c is derived as follows and is called a clock tick.

$$t_c = \text{num_units_in_tick} \div \text{time_scale} \quad (\text{C-1})$$

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.
- Let picture n be the primary coded picture or the decoded primary picture of access unit n .

C.1 Operation of coded picture buffer (CPB)

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.

C.1.1 Timing of bitstream arrival

The HRD may be initialised at any one of the buffering period SEI messages. Prior to initialisation, the CPB is empty.

NOTE – After initialisation, the HRD is not initialised again by subsequent buffering period SEI messages.

Each access unit is referred to as access unit n , where the number n identifies the particular access unit. The access unit that is associated with the buffering period SEI message that initializes the CPB is referred to as access unit 0. The value of n is incremented by 1 for each subsequent access unit in decoding order.

The time at which the first bit of access unit n begins to enter the CPB is referred to as the initial arrival time $t_{ai}(n)$.

The initial arrival time of access units is derived as follows.

- If the access unit is access unit 0, $t_{ai}(0) = 0$,
- Otherwise (the access unit is access unit n with $n > 0$), the following applies.
 - If $\text{cbr_flag}[\text{SchedSelIdx}]$ is equal to 1, the initial arrival time for access unit n , is equal to the final arrival time (which is derived below) of access unit $n - 1$, i.e.

$$t_{ai}(n) = t_{af}(n - 1) \quad (\text{C-2})$$

- Otherwise ($\text{cbr_flag}[\text{SchedSelIdx}]$ is equal to 0), the initial arrival time for access unit n is derived by

$$t_{ai}(n) = \text{Max}(t_{af}(n - 1), t_{ai,earliest}(n)) \quad (\text{C-3})$$

where $t_{ai,earliest}(n)$ is derived as follows

- If access unit n is not the first access unit of a subsequent buffering period, $t_{ai,earliest}(n)$ is derived as

$$t_{ai,earliest}(n) = t_{r,n}(n) - (\text{initial_cpb_removal_delay}[\text{SchedSelIdx}] + \text{initial_cpb_removal_delay_offset}[\text{SchedSelIdx}]) \div 90000 \quad (\text{C-4})$$

with $t_{r,n}(n)$ being the nominal removal time of access unit n from the CPB as specified in subclause C.1.2 and $\text{initial_cpb_removal_delay}[\text{SchedSelIdx}]$ and $\text{initial_cpb_removal_delay_offset}[\text{SchedSelIdx}]$ being specified in the previous buffering period SEI message.

- Otherwise (access unit n is the first access unit of a subsequent buffering period), $t_{ai,earliest}(n)$ is derived as

$$t_{ai,earliest}(n) = t_{r,n}(n) - (\text{initial_cpb_removal_delay}[\text{SchedSelIdx}] \div 90000) \quad (\text{C-5})$$

with $\text{initial_cpb_removal_delay}[\text{SchedSelIdx}]$ being specified in the buffering period SEI message associated with access unit n.

The final arrival time for access unit n is derived by

$$t_{af}(n) = t_{ai}(n) + b(n) \div \text{BitRate}[\text{SchedSelIdx}] \quad (\text{C-6})$$

where $b(n)$ is the size in bits of access unit n, 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 , $\text{BitRate}[\text{SchedSelIdx}]$, and $\text{CpbSize}[\text{SchedSelIdx}]$ are constrained as follows.

- If access unit n and access unit n - 1 are part of different coded video sequences and the content of the active sequence parameter sets of the two coded video sequences differ, the HSS selects a value SchedSelIdx1 of SchedSelIdx from among the values of SchedSelIdx provided for the coded video sequence containing access unit n that results in a $\text{BitRate}[\text{SchedSelIdx1}]$ or $\text{CpbSize}[\text{SchedSelIdx1}]$ for the second of the two coded video sequences (which contains access unit n). The value of $\text{BitRate}[\text{SchedSelIdx1}]$ or $\text{CpbSize}[\text{SchedSelIdx1}]$ may differ from the value of $\text{BitRate}[\text{SchedSelIdx0}]$ or $\text{CpbSize}[\text{SchedSelIdx0}]$ for the value SchedSelIdx0 of SchedSelIdx that was in use for the coded video sequence containing access unit n - 1.
- Otherwise, the HSS continues to operate with the previous values of SchedSelIdx , $\text{BitRate}[\text{SchedSelIdx}]$ and $\text{CpbSize}[\text{SchedSelIdx}]$.

When the HSS selects values of $\text{BitRate}[\text{SchedSelIdx}]$ or $\text{CpbSize}[\text{SchedSelIdx}]$ that differ from those of the previous access unit, the following applies.

- the variable $\text{BitRate}[\text{SchedSelIdx}]$ comes into effect at time $t_{ai}(n)$
- the variable $\text{CpbSize}[\text{SchedSelIdx}]$ comes into effect as follows.
 - If the new value of $\text{CpbSize}[\text{SchedSelIdx}]$ exceeds the old CPB size, it comes into effect at time $t_{ai}(n)$,
 - Otherwise, the new value of $\text{CpbSize}[\text{SchedSelIdx}]$ comes into effect at the time $t_r(n)$.

C.1.2 Timing of coded picture removal

For access unit 0, the nominal removal time of the access unit from the CPB is specified by

$$t_{r,n}(0) = \text{initial_cpb_removal_delay}[\text{SchedSelIdx}] \div 90000 \quad (\text{C-7})$$

For the first access unit of a buffering period that does not initialise the HRD, the nominal removal time of the access unit from the CPB is specified by

$$t_{r,n}(n) = t_{r,n}(n_b) + t_c * \text{cpb_removal_delay}(n) \quad (\text{C-8})$$

where $t_{r,n}(n_b)$ is the nominal removal time of the first access unit of the previous buffering period and $\text{cpb_removal_delay}(n)$ is the value of cpb_removal_delay specified in the picture timing SEI message associated with access unit n.

When an access unit n is the first access unit of a buffering period, n_b is set equal to n at the removal time of access unit n.

The nominal removal time $t_{r,n}(n)$ of an access unit n that is not the first access unit of a buffering period is given by

$$t_{r,n}(n) = t_{r,n}(n_b) + t_c * \text{cpb_removal_delay}(n) \quad (\text{C-9})$$

where $t_{r,n}(n_b)$ is the nominal removal time of the first access unit of the current buffering period and $\text{cpb_removal_delay}(n)$ is the value of cpb_removal_delay specified in the picture timing SEI message associated with access unit n.

The removal time of access unit n is specified as follows.

- If `low_delay_hrd_flag` is equal to 0 or $t_{r,n}(n) \geq t_{af}(n)$, the removal time of access unit n is specified by

$$t_r(n) = t_{r,n}(n) \quad (C-10)$$

- Otherwise (`low_delay_hrd_flag` is equal to 1 and $t_{r,n}(n) < t_{af}(n)$), the removal time of access unit n is specified by

$$t_r(n) = t_{r,n}(n) + t_c * \text{Ceil}((t_{af}(n) - t_{r,n}(n)) \div t_c) \quad (C-11)$$

NOTE – The latter case indicates that the size of access unit n , $b(n)$, is so large that it prevents removal at the nominal removal time.

C.2 Operation of the decoded picture buffer (DPB)

The decoded picture buffer contains frame buffers. Each of the frame buffers may contain a decoded frame, a decoded complementary field pair or a single (non-paired) decoded field that are marked as "used for reference" (reference pictures) or are held for future output (reordered or delayed pictures). Prior to initialisation, the DPB is empty (the DPB fullness is set to zero). The following steps of the subclauses of this subclause all happen instantaneously at $t_r(n)$ and in the sequence listed.

C.2.1 Decoding of gaps in frame_num and storage of "non-existing" frames

If applicable, gaps in `frame_num` are detected by the decoding process and the generated frames are marked and inserted into the DPB as specified below.

Gaps in `frame_num` are detected by the decoding process and the generated frames are marked as specified in subclause 8.2.5.2.

After the marking of each generated frame, each picture m marked by the "sliding window" process as "unused for reference" is removed from the DPB when it is also marked as "non-existing" or its DPB output time is less than or equal to the CPB removal time of the current picture n ; i.e., $t_{o,dpb}(m) \leq t_r(n)$. When a frame or the last field in a frame buffer is removed from the DPB, the DPB fullness is decremented by one. The "non-existing" generated frame is inserted into the DPB and the DPB fullness is incremented by one.

C.2.2 Picture decoding and output

Picture n is decoded and its DPB output time $t_{o,dpb}(n)$ is derived by

$$t_{o,dpb}(n) = t_r(n) + t_c * \text{dpb_output_delay}(n) \quad (C-12)$$

The output of the current picture is specified as follows.

- If $t_{o,dpb}(n) = t_r(n)$, the current picture is output.

NOTE – When the current picture is a reference picture it will be stored in the DPB.

- Otherwise ($t_{o,dpb}(n) > t_r(n)$), the current picture is output later and will be stored in the DPB (as specified in subclause C.2.4) and is output at time $t_{o,dpb}(n)$ 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 $t_{o,dpb}(n)$.

The output picture shall be cropped, using the cropping rectangle specified in the sequence parameter set for the sequence.

When picture n is a picture that is output and is not the last picture of the bitstream that is output, the value of $\Delta t_{o,dpb}(n)$ is defined as:

$$\Delta t_{o,dpb}(n) = t_{o,dpb}(n_n) - t_{o,dpb}(n) \quad (C-13)$$

where n_n indicates the picture that follows after picture n in output order.

The decoded picture is temporarily stored (not in the DPB).

C.2.3 Removal of pictures from the DPB before possible insertion of the current picture

The removal of pictures from the DPB before possible insertion of the current picture proceeds as follows.

- If the decoded picture is an IDR picture the following applies.

- All reference pictures in the DPB are marked as "unused for reference" as specified in subclause 8.2.5.1.
- When the IDR picture is not the first IDR picture decoded and the value of PicWidthInMbs or FrameHeightInMbs or max_dec_frame_buffering derived from the active sequence parameter set is different from the value of PicWidthInMbs or FrameHeightInMbs or max_dec_frame_buffering derived from the sequence parameter set that was active for the preceding sequence, respectively, no_output_of_prior_pics_flag is inferred to be equal to 1 by the HRD, regardless of the actual value of no_output_of_prior_pics_flag.

NOTE – Decoder implementations should try to handle frame or DPB size changes more gracefully than the HRD in regard to changes in PicWidthInMbs or FrameHeightInMbs.
- When no_output_of_prior_pics_flag is equal to 1 or is inferred to be equal to 1, all frame buffers in the DPB are emptied without output of the pictures they contain, and DPB fullness is set to 0.
- Otherwise (the decoded picture is not an IDR picture), the following applies.
 - If the slice header of the current picture includes memory_management_control_operation equal to 5, all reference pictures in the DPB are marked as "unused for reference".
 - Otherwise (the slice header of the current picture does not include memory_management_control_operation equal to 5), the decoded reference picture marking process specified in subclause 8.2.5 is invoked.

All pictures m in the DPB, for which all of the following conditions are true, are removed from the DPB.

- picture m is marked as "unused for reference" or picture m is a non-reference picture. When a picture is a reference frame, it is considered to be marked as "unused for reference" only when both of its fields have been marked as "unused for reference".
- picture m is marked as "non-existing" or its DPB output time is less than or equal to the CPB removal time of the current picture n ; i.e., $t_{o,dpb}(m) \leq t_r(n)$

When a frame or the last field in a frame buffer is removed from the DPB, the DPB fullness is decremented by one.

C.2.4 Current decoded picture marking and storage

C.2.4.1 Marking and storage of a reference decoded picture into the DPB

When the current picture is a reference picture it is stored in the DPB as follows.

- If the current decoded picture is a second field (in decoding order) of a complementary reference field pair, and the first field of the pair is still in the DPB, the current decoded picture is stored in the same frame buffer as the first field of the pair.
- Otherwise, the current decoded picture is stored in an empty frame buffer, and the DPB fullness is incremented by one.

C.2.4.2 Storage of a non-reference picture into the DPB

When the current picture is a non-reference picture and current picture n has $t_{o,dpb}(n) > t_r(n)$, it is stored in the DPB as follows.

- If the current decoded picture is a second field (in decoding order) of a complementary non-reference field pair, and the first field of the pair is still in the DPB, the current decoded picture is stored in the same frame buffer as the first field of the pair.
- Otherwise, the current decoded picture is stored in an empty frame buffer, and the DPB fullness is incremented by one.

C.3 Bitstream conformance

A bitstream of coded data conforming to this Recommendation | International Standard fulfils the following requirements.

The bitstream is constructed according to the syntax, semantics, and constraints specified in this Recommendation | International Standard outside of this Annex.

The bitstream is tested by the HRD as specified below:

For Type I bitstreams, the number of tests carried out is equal to $cpb_cnt_minus1 + 1$ where cpb_cnt_minus1 is either the syntax element of `hrd_parameters()` following the `vcl_hrd_parameters_present_flag` or is determined by the application by other means not specified in this Recommendation | International Standard. One test is carried out for

each bit rate and CPB size combination specified by `hrd_parameters()` following the `vcl_hrd_parameters_present_flag`. Each of these tests is conducted at the Type I conformance point shown in Figure C-1.

For Type II bitstreams there are two sets of tests. The number of tests of the first set is equal to `cpb_cnt_minus1 + 1` where `cpb_cnt_minus1` is either the syntax element of `hrd_parameters()` following the `vcl_hrd_parameters_present_flag` or is determined by the application by other means not specified in this Recommendation | International Standard. One test is carried out for each bit rate and CPB size combination. Each of these tests is conducted at the Type I conformance point shown in Figure C-1. For these tests, only VCL and filler data NAL units are counted for the input bit rate and CPB storage.

The number of tests of the second set, for Type II bitstreams, is equal to `cpb_cnt_minus1 + 1` where `cpb_cnt_minus1` is either the syntax element of `hrd_parameters()` following the `nal_hrd_parameters_present_flag` or is determined by the application by other means not specified in this Recommendation | International Standard. One test is carried out for each bit rate and CPB size combination specified by `hrd_parameters()` following the `nal_hrd_parameters_present_flag`. Each of these tests is conducted at the Type II conformance point shown in Figure C-1. For these tests, all NAL units (of a Type II NAL unit stream) or all bytes (of 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 `initial_cpb_removal_delay[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 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 *j* of subclause A.3.1 or item *i* of subclause A.3.3 (depending on the profile in use) but also fall within the bounds set for VCL HRD parameters for profile conformance in item *i* of subclause A.3.1 or item *h* of subclause A.3.3 (depending on the profile in use), conformance of the VCL HRD for the Type I conformance point is also assured to fall within the bounds of item *i* of subclause A.3.1.

For conforming bitstreams, all of the following conditions shall be fulfilled for each of the tests.

- For each access unit *n*, with $n > 0$, associated with a buffering period SEI message, with $\Delta t_{g,90}(n)$ specified by

$$\Delta t_{g,90}(n) = 90000 * (t_{r,n}(n) - t_{af}(n - 1)) \quad (C-14)$$

The value of `initial_cpb_removal_delay[SchedSelIdx]` shall be constrained as follows.

- If `cbr_flag[SchedSelIdx]` is equal to 0,

$$\text{initial_cpb_removal_delay[SchedSelIdx]} \leq \text{Ceil}(\Delta t_{g,90}(n)) \quad (C-15)$$

- Otherwise (`cbr_flag[SchedSelIdx]` is equal to 1),

$$\text{Floor}(\Delta t_{g,90}(n)) \leq \text{initial_cpb_removal_delay[SchedSelIdx]} \leq \text{Ceil}(\Delta t_{g,90}(n)) \quad (C-16)$$

NOTE 2 – 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 initialised at any one of the buffering period SEI messages.

- A CPB overflow is specified as the condition in which the total number of bits in the CPB is larger than the CPB size. The CPB shall never overflow.
- A CPB underflow is specified as the condition in which $t_{r,n}(n)$ is less than $t_{af}(n)$. When `low_delay_hrd_flag` is equal to 0, the CPB shall never underflow.
- The nominal removal times of pictures from the CPB (starting from the second picture in decoding order), shall satisfy the constraints on $t_{r,n}(n)$ and $t_r(n)$ expressed in subclauses A.3.1 through A.3.3 for the profile and level specified in the bitstream.
- Immediately after any decoded picture is added to the DPB, the fullness of the DPB shall be less than or equal to the DPB size as constrained by Annexes A, D, and E for the profile and level specified in the bitstream.
- All reference pictures shall be present in the DPB when needed for prediction. Each picture shall be present in the DPB at its DPB output time unless it is not stored in the DPB at all, or is removed from the DPB before its output time by one of the processes specified in subclause C.2.

- The value of $\Delta_{to,dpb}(n)$ as given by Equation C-13, which is the difference between the output time of a picture and that of the picture immediately following it in output order, shall satisfy the constraint expressed in subclause A.3.1 for the profile and level specified in the bitstream.

C.4 Decoder conformance

A decoder conforming to this Recommendation | International Standard fulfils the following requirements.

A decoder claiming conformance to a specific profile and level shall be able to decode successfully all conforming bitstreams specified for decoder conformance in subclause C.3, provided that all sequence parameter sets and picture parameters sets 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 by this Recommendation | International Standard.

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 and level, as specified by subclause C.3 are delivered by a hypothetical stream scheduler (HSS) both to the HRD and to the decoder under test (DUT). All pictures output by the HRD shall also be output by the DUT and, for each picture output by the HRD, the values of all samples that are output by the DUT for the corresponding picture shall be equal to the values of the samples output by the HRD.

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 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 DUT.

When the HRD parameters and the buffering period SEI messages are present with `cpb_cnt_minus1` 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 ($f(r) \div r$) as follows

$$\alpha = (r - \text{BitRate}[\text{SchedSelIdx} - 1]) \div (\text{BitRate}[\text{SchedSelIdx}] - \text{BitRate}[\text{SchedSelIdx} - 1]), \quad (\text{C-17})$$

$$c(r) = \alpha * \text{CpbSize}[\text{SchedSelIdx}] + (1 - \alpha) * \text{CpbSize}[\text{SchedSelIdx} - 1], \quad (\text{C-18})$$

$$f(r) = \alpha * \text{initial_cpb_removal_delay}[\text{SchedSelIdx}] * \text{BitRate}[\text{SchedSelIdx}] + (1 - \alpha) * \text{initial_cpb_removal_delay}[\text{SchedSelIdx} - 1] * \text{BitRate}[\text{SchedSelIdx} - 1] \quad (\text{C-19})$$

for any $\text{SchedSelIdx} > 0$ and r such that $\text{BitRate}[\text{SchedSelIdx} - 1] \leq r \leq \text{BitRate}[\text{SchedSelIdx}]$ 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 and level.

NOTE 1 – `initial_cpb_removal_delay[SchedSelIdx]` can be different from one buffering period to another and have to be recalculated.

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 HRD and the DUT up to a fixed delay.

For output order decoder conformance, the HSS delivers the bitstream 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 access 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 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 HRD and the DUT.

For output order decoder conformance, the HRD CPB size is equal to `CpbSize[SchedSelIdx]` for the selected schedule and the DPB size is equal to `MaxDpbSize`. Removal time from the CPB for the HRD is equal to final bit arrival time and decoding is immediate. The operation of the DPB of this HRD is described below.

C.4.1 Operation of the output order DPB

The decoded picture buffer contains frame buffers. Each of the frame buffers may contain a decoded frame, a decoded complementary field pair or a single (non-paired) decoded field that is marked as "used for reference" or is held for future output (reordered pictures). At HRD initialization, the DPB fullness, measured in frames, is set to 0. The following steps all happen instantaneously when an access unit is removed from the CPB, and in the order listed.

C.4.2 Decoding of gaps in frame_num and storage of "non-existing" pictures

When applicable, gaps in frame_num are detected by the decoding process and the necessary number of "non-existing" frames are inferred in the order specified by the generation of values of UnusedShortTermFrameNum in Equation 7-21 and are marked as specified in subclause 8.2.5.2. Frame buffers containing a frame or a complementary field pair or a non-paired field which are marked as "not needed for output" and "unused for reference" are emptied (without output), and the DPB fullness is decremented by the number of frame buffers emptied. Each "non-existing" frame is stored in the DPB as follows.

- When there is no empty frame buffer (i.e., DPB fullness is equal to DPB size), the "bumping" process specified in subclause C.4.5.3 is invoked repeatedly until there is an empty frame buffer in which to store the "non-existing" frame.
- The "non-existing" frame is stored in an empty frame buffer and is marked as "not needed for output", and the DPB fullness is incremented by one.

C.4.3 Picture decoding

Primary coded picture n is decoded and is temporarily stored (not in the DPB).

C.4.4 Removal of pictures from the DPB before possible insertion of the current picture

The removal of pictures from the DPB before possible insertion of the current picture proceeds as follows.

- If the decoded picture is an IDR picture the following applies.
 - All reference pictures in the DPB are marked as "unused for reference" as specified in subclause 8.2.5.
 - When the IDR picture is not the first IDR picture decoded and the value of PicWidthInMbs or FrameHeightInMbs or max_dec_frame_buffering derived from the active sequence parameter set is different from the value of PicWidthInMbs or FrameHeightInMbs or max_dec_frame_buffering derived from the sequence parameter set that was active for the preceding sequence, respectively, no_output_of_prior_pics_flag is inferred to be equal to 1 by the HRD, regardless of the actual value of no_output_of_prior_pics_flag.
NOTE – Decoder implementations should try to handle changes in the value of PicWidthInMbs or FrameHeightInMbs or max_dec_frame_buffering more gracefully than the HRD.
 - When no_output_of_prior_pics_flag is equal to 1 or is inferred to be equal to 1, all frame buffers in the DPB are emptied without output of the pictures they contain, and DPB fullness is set to 0.
- Otherwise (the decoded picture is not an IDR picture), the decoded reference picture marking process is invoked as specified in subclause 8.2.5. Frame buffers containing a frame or a complementary field pair or a non-paired field which are marked as "not needed for output" and "unused for reference" are emptied (without output), and the DPB fullness is decremented by the number of frame buffers emptied.

When the current picture has a memory_management_control_operation equal to 5 or is an IDR picture for which no_output_of_prior_pics_flag is not equal to 1 and is not inferred to be equal to 1, the following two steps are performed.

1. Frame buffers containing a frame or a complementary field pair or a non-paired field which are marked as "not needed for output" and "unused for reference" are emptied (without output), and the DPB fullness is decremented by the number of frame buffers emptied.
2. All non-empty frame buffers in the DPB are emptied by repeatedly invoking the "bumping" process specified in subclause C.4.5.3, and the DPB fullness is set to 0.

C.4.5 Current decoded picture marking and storage

C.4.5.1 Storage and marking of a reference decoded picture into the DPB

When the current picture is a reference picture, it is stored in the DPB as follows.

- If the current decoded picture is the second field (in decoding order) of a complementary reference field pair, and the first field of the pair is still in the DPB, the current picture is stored in the same frame buffer as the first field of the pair and is marked as "needed for output".

- Otherwise, the following operations are performed:
 - When there is no empty frame buffer (i.e., DPB fullness is equal to DPB size), the "bumping" process specified in subclause C.4.5.3 is invoked repeatedly until there is an empty frame buffer in which to store the current decoded picture.
 - The current decoded picture is stored in an empty frame buffer and is marked as "needed for output", and the DPB fullness is incremented by one.

C.4.5.2 Storage and marking of a non-reference decoded picture into the DPB

When the current picture is a non-reference picture, the following operations are performed.

- If the current decoded picture is the second field (in decoding order) of a complementary non-reference field pair and the first field of the pair is still in the DPB, the current picture is stored in the same frame buffer as the first field of the pair and is marked as "needed for output".
- Otherwise, the following operations are performed repeatedly until the current decoded picture has been cropped and output or has been stored in the DPB:
 - If there is no empty frame buffer (i.e., DPB fullness is equal to DPB size), the following applies.
 - If the current picture does not have a lower value of `PicOrderCnt()` than all pictures in the DPB that are marked as "needed for output", the "bumping" process described in subclause C.4.5.3 is performed.
 - Otherwise (the current picture has a lower value of `PicOrderCnt()` than all pictures in the DPB that are marked as "needed for output"), the current picture is cropped, using the cropping rectangle specified in the sequence parameter set for the sequence and the cropped picture is output.
 - Otherwise (there is an empty frame buffer, i.e., DPB fullness is less than DPB size) the current decoded picture is stored in an empty frame buffer and is marked as "needed for output", and the DPB fullness is incremented by one.

C.4.5.3 "Bumping" process

The "bumping" process is invoked in the following cases.

- There is no empty frame buffer (i.e., DPB fullness is equal to DPB size) and an empty frame buffer is needed for storage of an inferred "non-existing" frame, as specified in subclause C.4.2.
- The current picture is an IDR picture and `no_output_of_prior_pics_flag` is not equal to 1 and is not inferred to be equal to 1, as specified in subclause C.4.4.
- The current picture has `memory_management_control_operation` equal to 5, as specified in subclause C.4.4.
- There is no empty frame buffer (i.e., DPB fullness is equal to DPB size) and an empty frame buffer is needed for storage of a decoded (non-IDR) reference picture, as specified in subclause C.4.5.1.
- There is no empty frame buffer (i.e., DPB fullness is equal to DPB size) and the current picture is a non-reference picture that is not the second field of a complementary non-reference field pair and there are pictures in the DPB that are marked as "needed for output" that precede the current non-reference picture in output order, as specified in subclause C.4.5.2, so an empty buffer is needed for storage of the current picture.

The "bumping" process consists of the following:

- The picture or complementary reference field pair that is first for output is selected as follows.
 - The frame buffer is selected that contains the picture having the smallest value of `PicOrderCnt()` of all pictures in the DPB marked as "needed for output".
 - If this frame buffer contains a complementary non-reference field pair with both fields marked as "needed for output" and both fields have the same `PicOrderCnt()`, the first of these two fields in decoding order is considered first for output.
 - Otherwise, if this frame buffer contains a complementary reference field pair with both fields marked as "needed for output" and both fields have the same `PicOrderCnt()`, the entire complementary reference field pair is considered first for output.
 - Otherwise, the picture in this frame buffer that has the smallest value of `PicOrderCnt()` is considered first for output.
- If a single picture is considered first for output, this picture is cropped, using the cropping rectangle specified in the sequence parameter set for the sequence, the cropped picture is output, and the picture is marked as "not needed for output".

- Otherwise (a complementary reference field pair is considered first for output), the two fields of the complementary reference field pair are both cropped, using the cropping rectangle specified in the sequence parameter set for the sequence, the two fields of the complementary reference field pair are output together, and both fields of the complementary reference field pair are marked as "not needed for output".
- The frame buffer that included the picture or complementary reference field pair that was cropped and output is checked, and when any of the following conditions is satisfied, the frame buffer is emptied and the DPB fullness is decremented by 1.
 - The frame buffer contains a non-reference non-paired field.
 - The frame buffer contains a non-reference frame.
 - The frame buffer contains a complementary non-reference field pair with both fields marked as "not needed for output".
 - The frame buffer contains a non-paired reference field marked as "unused for reference".
 - The frame buffer contains a reference frame with both fields marked as "unused for reference".
 - The frame buffer contains a complementary reference field pair with both fields marked as "unused for reference" and "not needed for output".

Annex D

Supplemental enhancement information

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

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 Recommendation | International Standard (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 Annex D, 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 by this Recommendation | International Standard. When present in the bitstream, SEI messages shall obey the syntax and semantics specified in subclauses 7.3.2.3 and 7.4.2.3 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.1 SEI payload syntax

sei_payload(payloadType, payloadSize) {	C	Descriptor
if(payloadType == 0)		
buffering_period(payloadSize)	5	
else if(payloadType == 1)		
pic_timing(payloadSize)	5	
else if(payloadType == 2)		
pan_scan_rect(payloadSize)	5	
else if(payloadType == 3)		
filler_payload(payloadSize)	5	
else if(payloadType == 4)		
user_data_registered_itu_t_t35(payloadSize)	5	
else if(payloadType == 5)		
user_data_unregistered(payloadSize)	5	
else if(payloadType == 6)		
recovery_point(payloadSize)	5	
else if(payloadType == 7)		
dec_ref_pic_marking_repetition(payloadSize)	5	
else if(payloadType == 8)		
spare_pic(payloadSize)	5	
else if(payloadType == 9)		
scene_info(payloadSize)	5	
else if(payloadType == 10)		
sub_seq_info(payloadSize)	5	
else if(payloadType == 11)		
sub_seq_layer_characteristics(payloadSize)	5	
else if(payloadType == 12)		
sub_seq_characteristics(payloadSize)	5	
else if(payloadType == 13)		
full_frame_freeze(payloadSize)	5	
else if(payloadType == 14)		
full_frame_freeze_release(payloadSize)	5	
else if(payloadType == 15)		
full_frame_snapshot(payloadSize)	5	
else if(payloadType == 16)		
progressive_refinement_segment_start(payloadSize)	5	
else if(payloadType == 17)		
progressive_refinement_segment_end(payloadSize)	5	
else if(payloadType == 18)		
motion_constrained_slice_group_set(payloadSize)	5	
else if(payloadType == 19)		
film_grain_characteristics(payloadSize)	5	
else if(payloadType == 20)		
deblocking_filter_display_preference(payloadSize)	5	
else if(payloadType == 21)		
stereo_video_info(payloadSize)	5	
else		
reserved_sei_message(payloadSize)	5	

if(!byte_aligned()) {		
bit_equal_to_one /* equal to 1 */	5	f(1)
while(!byte_aligned())		
bit_equal_to_zero /* equal to 0 */	5	f(1)
}		
}		

D.1.1 Buffering period SEI message syntax

	C	Descriptor
buffering_period(payloadSize) {		
seq_parameter_set_id	5	ue(v)
if(NalHrdBpPresentFlag) {		
for(SchedSelIdx = 0; SchedSelIdx <= cpb_cnt_minus1; SchedSelIdx++) {		
initial_cpb_removal_delay [SchedSelIdx]	5	u(v)
initial_cpb_removal_delay_offset [SchedSelIdx]	5	u(v)
}		
}		
if(VclHrdBpPresentFlag) {		
for(SchedSelIdx = 0; SchedSelIdx <= cpb_cnt_minus1; SchedSelIdx++) {		
initial_cpb_removal_delay [SchedSelIdx]	5	u(v)
initial_cpb_removal_delay_offset [SchedSelIdx]	5	u(v)
}		
}		
}		

D.1.2 Picture timing SEI message syntax

	C	Descriptor
pic_timing(payloadSize) {		
if(CpbDpbDelaysPresentFlag) {		
cpb_removal_delay	5	u(v)
dpb_output_delay	5	u(v)
}		
if(pic_struct_present_flag) {		
pic_struct	5	u(4)
for(i = 0; i < NumClockTS ; i++) {		
clock_timestamp_flag [i]	5	u(1)
if(clock_timestamp_flag[i]) {		
ct_type	5	u(2)
nuit_field_based_flag	5	u(1)
counting_type	5	u(5)
full_timestamp_flag	5	u(1)
discontinuity_flag	5	u(1)
cnt_droppeded_flag	5	u(1)
n_frames	5	u(8)
if(full_timestamp_flag) {		
seconds_value /* 0..59 */	5	u(6)
}		
}		

minutes_value /* 0..59 */	5	u(6)
hours_value /* 0..23 */	5	u(5)
} else {		
seconds_flag	5	u(1)
if(seconds_flag) {		
seconds_value /* range 0..59 */	5	u(6)
minutes_flag	5	u(1)
if(minutes_flag) {		
minutes_value /* 0..59 */	5	u(6)
hours_flag	5	u(1)
if(hours_flag)		
hours_value /* 0..23 */	5	u(5)
}		
}		
}		
if(time_offset_length > 0)		
time_offset	5	i(v)
}		
}		
}		
}		

D.1.3 Pan-scan rectangle SEI message syntax

	C	Descriptor
pan_scan_rect(payloadSize) {		
pan_scan_rect_id	5	ue(v)
pan_scan_rect_cancel_flag	5	u(1)
if(!pan_scan_rect_cancel_flag) {		
pan_scan_cnt_minus1	5	ue(v)
for(i = 0; i <= pan_scan_cnt_minus1; i++) {		
pan_scan_rect_left_offset[i]	5	se(v)
pan_scan_rect_right_offset[i]	5	se(v)
pan_scan_rect_top_offset[i]	5	se(v)
pan_scan_rect_bottom_offset[i]	5	se(v)
}		
pan_scan_rect_repetition_period	5	ue(v)
}		
}		

D.1.4 Filler payload SEI message syntax

	C	Descriptor
filler_payload(payloadSize) {		
for(k = 0; k < payloadSize; k++)		
ff_byte /* equal to 0xFF */	5	f(8)
}		

D.1.5 User data registered by ITU-T Rec. T.35 SEI message syntax

	C	Descriptor
user_data_registered_itu_t_t35(payloadSize) {		
itu_t_t35_country_code	5	b(8)
if(itu_t_t35_country_code != 0xFF)		
i = 1		
else {		
itu_t_t35_country_code_extension_byte	5	b(8)
i = 2		
}		
do {		
itu_t_t35_payload_byte	5	b(8)
i++		
} while(i < payloadSize)		
}		

D.1.6 User data unregistered SEI message syntax

	C	Descriptor
user_data_unregistered(payloadSize) {		
uuid_iso_iec_11578	5	u(128)
for(i = 16; i < payloadSize; i++)		
user_data_payload_byte	5	b(8)
}		

D.1.7 Recovery point SEI message syntax

	C	Descriptor
recovery_point(payloadSize) {		
recovery_frame_cnt	5	ue(v)
exact_match_flag	5	u(1)
broken_link_flag	5	u(1)
changing_slice_group_idc	5	u(2)
}		

D.1.8 Decoded reference picture marking repetition SEI message syntax

	C	Descriptor
dec_ref_pic_marking_repetition(payloadSize) {		
original_idr_flag	5	u(1)
original_frame_num	5	ue(v)
if(!frame_mbs_only_flag) {		
original_field_pic_flag	5	u(1)
if(original_field_pic_flag)		
original_bottom_field_flag	5	u(1)
}		
dec_ref_pic_marking()	5	
}		

D.1.9 Spare picture SEI message syntax

	C	Descriptor
spare_pic(payloadSize) {		
target_frame_num	5	ue(v)
spare_field_flag	5	u(1)
if(spare_field_flag)		
target_bottom_field_flag	5	u(1)
num_spare_pics_minus1	5	ue(v)
for(i = 0; i < num_spare_pics_minus1 + 1; i++) {		
delta_spare_frame_num[i]	5	ue(v)
if(spare_field_flag)		
spare_bottom_field_flag[i]	5	u(1)
spare_area_idc[i]	5	ue(v)
if(spare_area_idc[i] == 1)		
for(j = 0; j < PicSizeInMapUnits; j++)		
spare_unit_flag[i][j]	5	u(1)
else if(spare_area_idc[i] == 2) {		
mapUnitCnt = 0		
for(j=0; mapUnitCnt < PicSizeInMapUnits; j++) {		
zero_run_length[i][j]	5	ue(v)
mapUnitCnt += zero_run_length[i][j] + 1		
}		
}		
}		
}		
}		

D.1.10 Scene information SEI message syntax

	C	Descriptor
scene_info(payloadSize) {		
scene_info_present_flag	5	u(1)
if(scene_info_present_flag) {		
scene_id	5	ue(v)
scene_transition_type	5	ue(v)
if(scene_transition_type > 3)		
second_scene_id	5	ue(v)
}		
}		

D.1.11 Sub-sequence information SEI message syntax

	C	Descriptor
sub_seq_info(payloadSize) {		
sub_seq_layer_num	5	ue(v)
sub_seq_id	5	ue(v)
first_ref_pic_flag	5	u(1)
leading_non_ref_pic_flag	5	u(1)
last_pic_flag	5	u(1)
sub_seq_frame_num_flag	5	u(1)
if(sub_seq_frame_num_flag)		
sub_seq_frame_num	5	ue(v)
}		

D.1.12 Sub-sequence layer characteristics SEI message syntax

	C	Descriptor
sub_seq_layer_characteristics(payloadSize) {		
num_sub_seq_layers_minus1	5	ue(v)
for(layer = 0; layer <= num_sub_seq_layers_minus1; layer++) {		
accurate_statistics_flag	5	u(1)
average_bit_rate	5	u(16)
average_frame_rate	5	u(16)
}		
}		

D.1.13 Sub-sequence characteristics SEI message syntax

	C	Descriptor
sub_seq_characteristics(payloadSize) {		
sub_seq_layer_num	5	ue(v)
sub_seq_id	5	ue(v)
duration_flag	5	u(1)
if(duration_flag)		
sub_seq_duration	5	u(32)
average_rate_flag	5	u(1)
if(average_rate_flag) {		
accurate_statistics_flag	5	u(1)
average_bit_rate	5	u(16)
average_frame_rate	5	u(16)
}		
num_referenced_subseqs	5	ue(v)
for(n = 0; n < num_referenced_subseqs; n++) {		
ref_sub_seq_layer_num	5	ue(v)
ref_sub_seq_id	5	ue(v)
ref_sub_seq_direction	5	u(1)
}		
}		

D.1.14 Full-frame freeze SEI message syntax

	C	Descriptor
full_frame_freeze(payloadSize) {		
full_frame_freeze_repetition_period	5	ue(v)
}		

D.1.15 Full-frame freeze release SEI message syntax

	C	Descriptor
full_frame_freeze_release(payloadSize) {		
}		

D.1.16 Full-frame snapshot SEI message syntax

	C	Descriptor
full_frame_snapshot(payloadSize) {		
snapshot_id	5	ue(v)
}		

D.1.17 Progressive refinement segment start SEI message syntax

	C	Descriptor
progressive_refinement_segment_start(payloadSize) {		
progressive_refinement_id	5	ue(v)
num_refinement_steps_minus1	5	ue(v)
}		

D.1.18 Progressive refinement segment end SEI message syntax

	C	Descriptor
progressive_refinement_segment_end(payloadSize) {		
progressive_refinement_id	5	ue(v)
}		

D.1.19 Motion-constrained slice group set SEI message syntax

	C	Descriptor
motion_constrained_slice_group_set(payloadSize) {		
num_slice_groups_in_set_minus1	5	ue(v)
for(i = 0; i <= num_slice_groups_in_set_minus1; i++)		
slice_group_id[i]	5	u(v)
exact_sample_value_match_flag	5	u(1)
pan_scan_rect_flag	5	u(1)
if(pan_scan_rect_flag)		
pan_scan_rect_id	5	ue(v)
}		

D.1.20 Film grain characteristics SEI message syntax

	C	Descriptor
film_grain_characteristics(payloadSize) {		
film_grain_characteristics_cancel_flag	5	u(1)
if(!film_grain_characteristics_cancel_flag) {		
model_id	5	u(2)
separate_colour_description_present_flag	5	u(1)
if(separate_colour_description_present_flag) {		
film_grain_bit_depth_luma_minus8	5	u(3)
film_grain_bit_depth_chroma_minus8	5	u(3)
film_grain_full_range_flag	5	u(1)
film_grain_colour primaries	5	u(8)
film_grain_transfer_characteristics	5	u(8)
film_grain_matrix_coefficients	5	u(8)
}		
blending_mode_id	5	u(2)
log2_scale_factor	5	u(4)
for(c = 0; c < 3; c++)		
comp_model_present_flag[c]	5	u(1)
for(c = 0; c < 3; c++)		
if(comp_model_present_flag[c]) {		
num_intensity_intervals_minus1[c]	5	u(8)
num_model_values_minus1[c]	5	u(3)
for(i = 0; i <= num_intensity_intervals_minus1[c]; i++) {		
intensity_interval_lower_bound[c][i]	5	u(8)
intensity_interval_upper_bound[c][i]	5	u(8)
for(j = 0; j <= num_model_values_minus1[c]; j++)		
comp_model_value[c][i][j]	5	se(v)
}		
}		
}		
film_grain_characteristics_repetition_period	5	ue(v)
}		
}		

D.1.21 Deblocking filter display preference SEI message syntax

	C	Descriptor
deblocking_filter_display_preference(payloadSize) {		
deblocking_display_preference_cancel_flag	5	u(1)
if(!deblocking_display_preference_cancel_flag) {		
display_prior_to_deblocking_preferred_flag	5	u(1)
dec_frame_buffering_constraint_flag	5	u(1)
deblocking_display_preference_repetition_period	5	ue(v)
}		
}		

D.1.22 Stereo video information SEI message syntax

	C	Descriptor
stereo_video_info(payloadSize) {		
field_views_flag	5	u(1)
if(field_views_flag)		
top_field_is_left_view_flag	5	u(1)
else {		
current_frame_is_left_view_flag	5	u(1)
next_frame_is_second_view_flag	5	u(1)
}		
left_view_self_contained_flag	5	u(1)
right_view_self_contained_flag	5	u(1)
}		

D.1.23 Reserved SEI message syntax

	C	Descriptor
reserved_sei_message(payloadSize) {		
for(i = 0; i < payloadSize; i++)		
reserved_sei_message_payload_byte	5	b(8)
}		

D.2 SEI payload semantics

D.2.1 Buffering period SEI message semantics

When NalHrdBpPresentFlag or VclHrdBpPresentFlag are equal to 1, a buffering period SEI message can be associated with any access unit in the bitstream, and a buffering period SEI message shall be associated with each IDR access unit and with each access unit associated with a recovery point SEI message.

NOTE – For some applications, the frequent presence of a buffering period SEI message may be desirable.

A buffering period is specified as the set of access units between two instances of the buffering period SEI message in decoding order.

seq_parameter_set_id specifies the sequence parameter set that contains the sequence HRD attributes. The value of seq_parameter_set_id shall be equal to the value of seq_parameter_set_id in the picture parameter set referenced by the primary coded picture associated with the buffering period SEI message. The value of seq_parameter_set_id shall be in the range of 0 to 31, inclusive.

initial_cpb_removal_delay[SchedSelIdx] specifies the delay for the SchedSelIdx-th CPB between the time of arrival in the CPB of the first bit of the coded data associated with the access unit associated with the buffering period SEI message and the time of removal from the CPB of the coded data associated with the same access unit, for the first buffering period after HRD initialisation. The syntax element has a length in bits given by initial_cpb_removal_delay_length_minus1 + 1. It is in units of a 90 kHz clock. initial_cpb_removal_delay[SchedSelIdx] shall not be equal to 0 and shall not exceed $90000 * (CpbSize[SchedSelIdx] \div BitRate[SchedSelIdx])$, the time-equivalent of the CPB size in 90 kHz clock units.

initial_cpb_removal_delay_offset[SchedSelIdx] is used for the SchedSelIdx-th CPB in combination with the cpb_removal_delay to specify the initial delivery time of coded access units to the CPB. initial_cpb_removal_delay_offset[SchedSelIdx] is in units of a 90 kHz clock. The initial_cpb_removal_delay_offset[SchedSelIdx] syntax element is a fixed length code whose length in bits is given by initial_cpb_removal_delay_length_minus1 + 1. This syntax element is not used by decoders and is needed only for the delivery scheduler (HSS) specified in Annex C.

Over the entire coded video sequence, the sum of initial_cpb_removal_delay[SchedSelIdx] and initial_cpb_removal_delay_offset[SchedSelIdx] shall be constant for each value of SchedSelIdx.

D.2.2 Picture timing SEI message semantics

The presence of picture timing SEI message in the bitstream is specified as follows.

- If `CpbDpbDelaysPresentFlag` is equal to 1 or `pic_struct_present_flag` is equal to 1, one picture timing SEI message shall be present in every access unit of the coded video sequence.
- Otherwise (`CpbDpbDelaysPresentFlag` is equal to 0 and `pic_struct_present_flag` is equal to 0), no picture timing SEI messages shall be present in any access unit of the coded video sequence.

cpb_removal_delay specifies how many clock ticks (see subclause E.2.1) to wait after removal from the CPB of the access unit associated with the most recent buffering period SEI message before removing from the buffer the access unit data associated with the picture timing SEI message. This value is also used to calculate an earliest possible time of arrival of access unit data into the CPB for the HSS, as specified in Annex C. The syntax element is a fixed length code whose length in bits is given by `cpb_removal_delay_length_minus1 + 1`. The `cpb_removal_delay` is the remainder of a $2^{(\text{cpb_removal_delay_length_minus1} + 1)}$ counter.

The value of `cpb_removal_delay` for the first picture in the bitstream shall be equal to 0.

dpb_output_delay is used to compute the DPB output time of the picture. It specifies how many clock ticks to wait after removal of an access unit from the CPB before the decoded picture can be output from the DPB (see subclause C.2).

NOTE 1 – A picture is not removed from the DPB at its output time when it is still marked as "used for short-term reference" or "used for long-term reference".

NOTE 2 – Only one `dpb_output_delay` is specified for a decoded picture.

The size of the syntax element `dpb_output_delay` is given in bits by `dpb_output_delay_length_minus1 + 1`. When `max_dec_frame_buffering` is equal to 0, `dpb_output_delay` shall be equal to 0.

The output time derived from the `dpb_output_delay` of any picture that is output from an output timing conforming decoder as specified in subclause C.2 shall precede the output time derived from the `dpb_output_delay` of all pictures in any subsequent coded video sequence in decoding order.

The output time derived from the `dpb_output_delay` of the second field, in decoding order, of a complementary non-reference field pair shall exceed the output time derived from the `dpb_output_delay` of the first field of the same complementary non-reference field pair.

The picture output order established by the values of this syntax element shall be the same order as established by the values of `PicOrderCnt()` as specified by subclauses C.4.1 to C.4.5, except that when the two fields of a complementary reference field pair have the same value of `PicOrderCnt()`, the two fields have different output times.

For pictures that are not output by the "bumping" process of subclause C.4.5 because they precede, in decoding order, an IDR picture with `no_output_of_prior_pics_flag` equal to 1 or inferred to be equal to 1, the output times derived from `dpb_output_delay` shall be increasing with increasing value of `PicOrderCnt()` relative to all pictures within the same coded video sequence subsequent to any picture having a `memory_management_control_operation` equal to 5.

pic_struct indicates whether a picture should be displayed as a frame or one or more fields, according to Table D-1. Frame doubling (`pic_struct` equal to 7) indicates that the frame should be displayed two times consecutively, and frame tripling (`pic_struct` equal to 8) indicates that the frame should be displayed three times consecutively.

NOTE 3 – Frame doubling can facilitate the display, for example, of 25p video on a 50p display and 29.97p video on a 59.94p display. Using frame doubling and frame tripling in combination on every other frame can facilitate the display of 23.98p video on a 59.94p display.

Table D-1 – Interpretation of pic_struct

Value	Indicated display of picture	Restrictions	NumClockTS
0	frame	field_pic_flag shall be 0	1
1	top field	field_pic_flag shall be 1, bottom_field_flag shall be 0	1
2	bottom field	field_pic_flag shall be 1, bottom_field_flag shall be 1	1
3	top field, bottom field, in that order	field_pic_flag shall be 0	2
4	bottom field, top field, in that order	field_pic_flag shall be 0	2
5	top field, bottom field, top field repeated, in that order	field_pic_flag shall be 0	3
6	bottom field, top field, bottom field repeated, in that order	field_pic_flag shall be 0	3
7	frame doubling	field_pic_flag shall be 0 fixed_frame_rate_flag shall be 1	2
8	frame tripling	field_pic_flag shall be 0 fixed_frame_rate_flag shall be 1	3
9..15	reserved		

NumClockTS is determined by pic_struct as specified in Table D-1. There are up to NumClockTS sets of clock timestamp information for a picture, as specified by clock_timestamp_flag[i] for each set. The sets of clock timestamp information apply to the field(s) or the frame(s) associated with the picture by pic_struct.

The contents of the clock timestamp syntax elements indicate a time of origin, capture, or alternative ideal display. This indicated time is computed as

$$\text{clockTimestamp} = ((\text{hH} * 60 + \text{mM}) * 60 + \text{sS}) * \text{time_scale} + \text{nFrames} * (\text{num_units_in_tick} * (1 + \text{nuit_field_based_flag})) + \text{tOffset}, \quad (\text{D-1})$$

in units of clock ticks of a clock with clock frequency equal to time_scale Hz, relative to some unspecified point in time for which clockTimestamp is equal to 0. Output order and DPB output timing are not affected by the value of clockTimestamp. When two or more frames with pic_struct equal to 0 are consecutive in output order and have equal values of clockTimestamp, the indication is that the frames represent the same content and that the last such frame in output order is the preferred representation.

NOTE 4 – clockTimestamp time indications may aid display on devices with refresh rates other than those well-matched to DPB output times.

clock_timestamp_flag[i] equal to 1 indicates that a number of clock timestamp syntax elements are present and follow immediately. clock_timestamp_flag[i] equal to 0 indicates that the associated clock timestamp syntax elements are not present. When NumClockTS is greater than 1 and clock_timestamp_flag[i] is equal to 1 for more than one value of i, the value of clockTimestamp shall be non-decreasing with increasing value of i.

ct_type indicates the scan type (interlaced or progressive) of the source material as specified in Table D-2.

Two fields of a coded frame may have different values of ct_type.

When clockTimestamp is equal for two fields of opposite parity that are consecutive in output order, both with ct_type equal to 0 (progressive) or ct_type equal to 2 (unknown), the two fields are indicated to have come from the same original progressive frame. Two consecutive fields in output order shall have different values of clockTimestamp when the value of ct_type for either field is 1 (interlaced).

Table D-2 – Mapping of ct_type to source picture scan

Value	Original picture scan
0	progressive
1	interlaced
2	unknown
3	reserved

nuit_field_based_flag is used in calculating clockTimestamp, as specified in Equation D-1.

counting_type specifies the method of dropping values of the n_frames as specified in Table D-3.

Table D-3 – Definition of counting_type values

Value	Interpretation
0	no dropping of n_frames count values and no use of time_offset
1	no dropping of n_frames count values
2	dropping of individual zero values of n_frames count
3	dropping of individual MaxFPS-1 values of n_frames count
4	dropping of the two lowest (value 0 and 1) n_frames counts when seconds_value is equal to 0 and minutes_value is not an integer multiple of 10
5	dropping of unspecified individual n_frames count values
6	dropping of unspecified numbers of unspecified n_frames count values
7..31	reserved

full_timestamp_flag equal to 1 specifies that the n_frames syntax element is followed by seconds_value, minutes_value, and hours_value. full_timestamp_flag equal to 0 specifies that the n_frames syntax element is followed by seconds_flag.

discontinuity_flag equal to 0 indicates that the difference between the current value of clockTimestamp and the value of clockTimestamp computed from the previous clock timestamp in output order can be interpreted as the time difference between the times of origin or capture of the associated frames or fields. discontinuity_flag equal to 1 indicates that the difference between the current value of clockTimestamp and the value of clockTimestamp computed from the previous clock timestamp in output order should not be interpreted as the time difference between the times of origin or capture of the associated frames or fields. When discontinuity_flag is equal to 0, the value of clockTimestamp shall be greater than or equal to all values of clockTimestamp present for the preceding picture in DPB output order.

cnt_dropped_flag specifies the skipping of one or more values of n_frames using the counting method specified by counting_type.

n_frames specifies the value of nFrames used to compute clockTimestamp. n_frames shall be less than

$$\text{MaxFPS} = \text{Ceil}(\text{time_scale} \div \text{num_units_in_tick}) \quad (\text{D-2})$$

NOTE 5 – n_frames is a frame-based counter. For field-specific timing indications, time_offset should be used to indicate a distinct clockTimestamp for each field.

When `counting_type` is equal to 2 and `cnt_dropped_flag` is equal to 1, `n_frames` shall be equal to 1 and the value of `n_frames` for the previous picture in output order shall not be equal to 0 unless `discontinuity_flag` is equal to 1.

NOTE 6 – When `counting_type` is equal to 2, the need for increasingly large magnitudes of `tOffset` in Equation D-1 when using fixed non-integer frame rates (e.g., 12.5 frames per second with `time_scale` equal to 25 and `num_units_in_tick` equal to 2 and `nuit_field_based_flag` equal to 0) can be avoided by occasionally skipping over the value `n_frames` equal to 0 when counting (e.g., counting `n_frames` from 0 to 12, then incrementing `seconds_value` and counting `n_frames` from 1 to 12, then incrementing `seconds_value` and counting `n_frames` from 0 to 12, etc.).

When `counting_type` is equal to 3 and `cnt_dropped_flag` is equal to 1, `n_frames` shall be equal to 0 and the value of `n_frames` for the previous picture in output order shall not be equal to `MaxFPS` – 1 unless `discontinuity_flag` is equal to 1.

NOTE 7 – When `counting_type` is equal to 3, the need for increasingly large magnitudes of `tOffset` in Equation D-1 when using fixed non-integer frame rates (e.g., 12.5 frames per second with `time_scale` equal to 25 and `num_units_in_tick` equal to 2 and `nuit_field_based_flag` equal to 0) can be avoided by occasionally skipping over the value `n_frames` equal to `MaxFPS` when counting (e.g., counting `n_frames` from 0 to 12, then incrementing `seconds_value` and counting `n_frames` from 0 to 11, then incrementing `seconds_value` and counting `n_frames` from 0 to 12, etc.).

When `counting_type` is equal to 4 and `cnt_dropped_flag` is equal to 1, `n_frames` shall be equal to 2 and the specified value of `sS` shall be zero and the specified value of `mM` shall not be an integer multiple of ten and `n_frames` for the previous picture in output order shall not be equal to 0 or 1 unless `discontinuity_flag` is equal to 1.

NOTE 8 – When `counting_type` is equal to 4, the need for increasingly large magnitudes of `tOffset` in Equation D-1 when using fixed non-integer frame rates (e.g., 30000÷1001 frames per second with `time_scale` equal to 60000 and `num_units_in_tick` equal to 1 001 and `nuit_field_based_flag` equal to 1) can be reduced by occasionally skipping over the value `n_frames` equal to `MaxFPS` when counting (e.g., counting `n_frames` from 0 to 29, then incrementing `seconds_value` and counting `n_frames` from 0 to 29, etc., until the `seconds_value` is zero and `minutes_value` is not an integer multiple of ten, then counting `n_frames` from 2 to 29, then incrementing `seconds_value` and counting `n_frames` from 0 to 29, etc.). This counting method is well known in industry and is often referred to as "NTSC drop-frame" counting.

When `counting_type` is equal to 5 or 6 and `cnt_dropped_flag` is equal to 1, `n_frames` shall not be equal to 1 plus the value of `n_frames` for the previous picture in output order modulo `MaxFPS` unless `discontinuity_flag` is equal to 1.

NOTE 9 – When `counting_type` is equal to 5 or 6, the need for increasingly large magnitudes of `tOffset` in Equation D-1 when using fixed non-integer frame rates can be avoided by occasionally skipping over some values of `n_frames` when counting. The specific values of `n_frames` that are skipped are not specified when `counting_type` is equal to 5 or 6.

seconds_flag equal to 1 specifies that `seconds_value` and `minutes_flag` are present when `full_timestamp_flag` is equal to 0. `seconds_flag` equal to 0 specifies that `seconds_value` and `minutes_flag` are not present.

seconds_value specifies the value of `sS` used to compute `clockTimestamp`. The value of `seconds_value` shall be in the range of 0 to 59, inclusive. When `seconds_value` is not present, the previous `seconds_value` in decoding order shall be used as `sS` to compute `clockTimestamp`.

minutes_flag equal to 1 specifies that `minutes_value` and `hours_flag` are present when `full_timestamp_flag` is equal to 0 and `seconds_flag` is equal to 1. `minutes_flag` equal to 0 specifies that `minutes_value` and `hours_flag` are not present.

minutes_value specifies the value of `mM` used to compute `clockTimestamp`. The value of `minutes_value` shall be in the range of 0 to 59, inclusive. When `minutes_value` is not present, the previous `minutes_value` in decoding order shall be used as `mM` to compute `clockTimestamp`.

hours_flag equal to 1 specifies that `hours_value` is present when `full_timestamp_flag` is equal to 0 and `seconds_flag` is equal to 1 and `minutes_flag` is equal to 1.

hours_value specifies the value of `hH` used to compute `clockTimestamp`. The value of `hours_value` shall be in the range of 0 to 23, inclusive. When `hours_value` is not present, the previous `hours_value` in decoding order shall be used as `hH` to compute `clockTimestamp`.

time_offset specifies the value of `tOffset` used to compute `clockTimestamp`. The number of bits used to represent `time_offset` shall be equal to `time_offset_length`. When `time_offset` is not present, the value 0 shall be used as `tOffset` to compute `clockTimestamp`.

D.2.3 Pan-scan rectangle SEI message semantics

The pan-scan rectangle SEI message syntax elements specify the coordinates of a rectangle relative to the cropping rectangle of the sequence parameter set. Each coordinate of this rectangle is specified in units of one-sixteenth sample spacing relative to the luma sampling grid.

pan_scan_rect_id contains an identifying number that may be used to identify the purpose of the pan-scan rectangle (for example, to identify the rectangle as the area to be shown on a particular display device or as the area that contains a particular actor in the scene). The value of `pan_scan_rect_id` shall be in the range of 0 to $2^{32} - 1$, inclusive.

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

`pan_scan_rect_cancel_flag` equal to 1 indicates that the SEI message cancels the persistence of any previous pan-scan rectangle SEI message in output order. `pan_scan_rect_cancel_flag` equal to 0 indicates that pan-scan rectangle information follows.

`pan_scan_cnt_minus1` specifies the number of pan-scan rectangles that are present in the SEI message. `pan_scan_cnt_minus1` shall be in the range of 0 to 2, inclusive. `pan_scan_cnt_minus1` equal to 0 indicates that a single pan-scan rectangle is present that applies to all fields of the decoded picture. `pan_scan_cnt_minus1` shall be equal to 0 when the current picture is a field. `pan_scan_cnt_minus1` equal to 1 indicates that two pan-scan rectangles are present, the first of which applies to the first field of the picture in output order and the second of which applies to the second field of the picture in output order. `pan_scan_cnt_minus1` equal to 2 indicates that three pan-scan rectangles are present, the first of which applies to the first field of the picture in output order, the second of which applies to the second field of the picture in output order, and the third of which applies to a repetition of the first field as a third field in output order.

`pan_scan_rect_left_offset[i]`, `pan_scan_rect_right_offset[i]`, `pan_scan_rect_top_offset[i]`, and `pan_scan_rect_bottom_offset[i]`, specify, as signed integer quantities in units of one-sixteenth sample spacing relative to the luma sampling grid, the location of the pan-scan rectangle. The values of each of these four syntax elements shall be in the range of -2^{31} to $2^{31} - 1$, inclusive.

The pan-scan rectangle is specified, in units of one-sixteenth sample spacing relative to a luma frame sampling grid, as the region with frame horizontal coordinates from $16 * \text{CropUnitX} * \text{frame_crop_left_offset} + \text{pan_scan_rect_left_offset}[i]$ to $16 * (16 * \text{PicWidthInMbs} - \text{CropUnitX} * \text{frame_crop_right_offset}) + \text{pan_scan_rect_right_offset}[i] - 1$ and with vertical coordinates from $16 * \text{CropUnitY} * \text{frame_crop_top_offset} + \text{pan_scan_rect_top_offset}[i]$ to $16 * (16 * \text{PicHeightInMbs} - \text{CropUnitY} * \text{frame_crop_bottom_offset}) + \text{pan_scan_rect_bottom_offset}[i] - 1$, inclusive. The value of $16 * \text{CropUnitX} * \text{frame_crop_left_offset} + \text{pan_scan_rect_left_offset}[i]$ shall be less than or equal to $16 * (16 * \text{PicWidthInMbs} - \text{CropUnitX} * \text{frame_crop_right_offset}) + \text{pan_scan_rect_right_offset}[i] - 1$; and the value of $16 * \text{CropUnitY} * \text{frame_crop_top_offset} + \text{pan_scan_rect_top_offset}[i]$ shall be less than or equal to $16 * (16 * \text{PicHeightInMbs} - \text{CropUnitY} * \text{frame_crop_bottom_offset}) + \text{pan_scan_rect_bottom_offset}[i] - 1$.

When the pan-scan rectangular area includes samples outside of the cropping rectangle, the region outside of the cropping rectangle may be filled with synthesized content (such as black video content or neutral grey video content) for display.

`pan_scan_rect_repetition_period` specifies the persistence of the pan-scan rectangle SEI message and may specify a picture order count interval within which another pan-scan rectangle SEI message with the same value of `pan_scan_rect_id` or the end of the coded video sequence shall be present in the bitstream. The value of `pan_scan_rect_repetition_period` shall be in the range of 0 to 16 384, inclusive. When `pan_scan_cnt_minus1` is greater than 0, `pan_scan_rect_repetition_period` shall not be greater than 1.

`pan_scan_rect_repetition_period` equal to 0 specifies that the pan-scan rectangle information applies to the current decoded picture only.

`pan_scan_rect_repetition_period` equal to 1 specifies that the pan-scan rectangle information persists in output order until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a pan-scan rectangle SEI message with the same value of `pan_scan_rect_id` is output having `PicOrderCnt()` greater than `PicOrderCnt(CurrPic)`.

`pan_scan_rect_repetition_period` equal to 0 or equal to 1 indicates that another pan-scan rectangle SEI message with the same value of `pan_scan_rect_id` may or may not be present.

`pan_scan_rect_repetition_period` greater than 1 specifies that the pan-scan rectangle information persists until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a pan-scan rectangle SEI message with the same value of `pan_scan_rect_id` is output having `PicOrderCnt()` greater than `PicOrderCnt(CurrPic)` and less than or equal to `PicOrderCnt(CurrPic) + pan_scan_rect_repetition_period`.

`pan_scan_rect_repetition_period` greater than 1 indicates that another pan-scan rectangle SEI message with the same value of `pan_scan_rect_id` shall be present for a picture in an access unit that is output having `PicOrderCnt()` greater

than $\text{PicOrderCnt}(\text{CurrPic})$ and less than or equal to $\text{PicOrderCnt}(\text{CurrPic}) + \text{pan_scan_rect_repetition_period}$; unless the bitstream ends or a new coded video sequence begins without output of such a picture.

D.2.4 Filler payload SEI message semantics

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

ff_byte shall be a byte having the value 0xFF.

D.2.5 User data registered by ITU-T Rec. T.35 SEI message semantics

This message contains user data registered as specified by ITU-T Rec. T.35, the contents of which are not specified by this Recommendation | International Standard.

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

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

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

The ITU-T T.35 terminal provider code and terminal provider oriented code shall be contained in the first one or more bytes of the **itu_t_t35_payload_byte**, in the format specified by the Administration that issued the terminal provider code. Any remaining **itu_t_t35_payload_byte** data shall be data having syntax and semantics as specified by the entity identified by the ITU-T T.35 country code and terminal provider code.

D.2.6 User data unregistered SEI message semantics

This message contains unregistered user data identified by a UUID, the contents of which are not specified by this Recommendation | International Standard.

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

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

D.2.7 Recovery point SEI message semantics

The recovery point SEI message assists a decoder in determining when the decoding process will produce acceptable pictures for display after the decoder initiates random access or after the encoder indicates a broken link in the sequence. When the decoding process is started with the access unit in decoding order associated with the recovery point SEI message, all decoded pictures at or subsequent to the recovery point in output order specified in this SEI message are indicated to be correct or approximately correct in content. Decoded pictures produced by random access at or before the picture associated with the recovery point SEI message need not be correct in content until the indicated recovery point, and the operation of the decoding process starting at the picture associated with the recovery point SEI message may contain references to pictures not available in the decoded picture buffer.

In addition, by use of the **broken_link_flag**, the recovery point SEI message can indicate to the decoder the location of some pictures in the bitstream that can result in serious visual artefacts when displayed, even when the decoding process was begun at the location of a previous IDR access unit in decoding order.

NOTE 1 – The **broken_link_flag** can be used by encoders to indicate the location of a point after which the decoding process for the decoding of some pictures may cause references to pictures that, though available for use in the decoding process, are not the pictures that were used for reference when the bitstream was originally encoded (e.g., due to a splicing operation performed during the generation of the bitstream).

The recovery point is specified as a count in units of frame_num increments subsequent to the frame_num of the current access unit at the position of the SEI message.

NOTE 2 – When HRD information is present in the bitstream, a buffering period SEI message should be associated with the access unit associated with the recovery point SEI message in order to establish initialisation of the HRD buffer model after a random access.

recovery_frame_cnt specifies the recovery point of output pictures in output order. All decoded pictures in output order are indicated to be correct or approximately correct in content starting at the output order position of the reference picture having the frame_num equal to the frame_num of the VCL NAL units for the current access unit incremented by **recovery_frame_cnt** in modulo MaxFrameNum arithmetic. **recovery_frame_cnt** shall be in the range of 0 to $\text{MaxFrameNum} - 1$, inclusive.

exact_match_flag indicates whether decoded pictures at and subsequent to the specified recovery point in output order derived by starting the decoding process at the access unit associated with the recovery point SEI message shall be an

exact match to the pictures that would be produced by starting the decoding process at the location of a previous IDR access unit in the NAL unit stream. The value 0 indicates that the match need not be exact and the value 1 indicates that the match shall be exact.

When decoding starts from the location of the recovery point SEI message, all references to not available reference pictures shall be inferred as references to pictures containing only macroblocks coded using Intra macroblock prediction modes and having sample values given by Y samples equal to 128, Cb samples equal to 128, and Cr samples equal to 128 (mid-level grey) for purposes of determining the conformance of the value of `exact_match_flag`.

NOTE 3 – When performing random access, decoders should infer all references to not available reference pictures as references to pictures containing only intra macroblocks and having sample values given by Y equal to 128, Cb equal to 128, and Cr equal to 128 (mid-level grey), regardless of the value of `exact_match_flag`.

When `exact_match_flag` is equal to 0, the quality of the approximation at the recovery point is chosen by the encoding process and is not specified by this Recommendation | International Standard.

broken_link_flag indicates the presence or absence of a broken link in the NAL unit stream at the location of the recovery point SEI message and is assigned further semantics as follows.

- If `broken_link_flag` is equal to 1, pictures produced by starting the decoding process at the location of a previous IDR access unit may contain undesirable visual artefacts to the extent that decoded pictures at and subsequent to the access unit associated with the recovery point SEI message in decoding order should not be displayed until the specified recovery point in output order.
- Otherwise (`broken_link_flag` is equal to 0), no indication is given regarding any potential presence of visual artefacts.

Regardless of the value of the `broken_link_flag`, pictures subsequent to the specified recovery point in output order are specified to be correct or approximately correct in content.

NOTE 4 – When a sub-sequence information SEI message is present in conjunction with a recovery point SEI message in which `broken_link_flag` is equal to 1 and when `sub_seq_layer_num` is equal to 0, `sub_seq_id` should be different from the latest `sub_seq_id` for `sub_seq_layer_num` equal to 0 that was decoded prior to the location of the recovery point SEI message. When `broken_link_flag` is equal to 0, the `sub_seq_id` in sub-sequence layer 0 should remain unchanged.

changing_slice_group_idc equal to 0 indicates that decoded pictures are correct or approximately correct in content at and subsequent to the recovery point in output order when all macroblocks of the primary coded pictures are decoded within the changing slice group period, i.e., the period between the access unit associated with the recovery point SEI message (inclusive) and the specified recovery point (inclusive) in decoding order. `changing_slice_group_idc` shall be equal to 0 when `num_slice_groups_minus1` is equal to 0 in any primary coded picture within the changing slice group period.

When `changing_slice_group_idc` is equal to 1 or 2, `num_slice_groups_minus1` shall be equal to 1 and the macroblock-to-slice-group map type 3, 4, or 5 shall be applied in each primary coded picture in the changing slice group period.

`changing_slice_group_idc` equal to 1 indicates that within the changing slice group period no sample values outside the decoded macroblocks covered by slice group 0 are used for inter prediction of any macroblock within slice group 0. In addition, `changing_slice_group_idc` equal to 1 indicates that when all macroblocks in slice group 0 within the changing slice group period are decoded, decoded pictures will be correct or approximately correct in content at and subsequent to the specified recovery point in output order regardless of whether any macroblock in slice group 1 within the changing slice group period is decoded.

`changing_slice_group_idc` equal to 2 indicates that within the changing slice group period no sample values outside the decoded macroblocks covered by slice group 1 are used for inter prediction of any macroblock within slice group 1. In addition, `changing_slice_group_idc` equal to 2 indicates that when all macroblocks in slice group 1 within the changing slice group period are decoded, decoded pictures will be correct or approximately correct in content at and subsequent to the specified recovery point in output order regardless of whether any macroblock in slice group 0 within the changing slice group period is decoded.

`changing_slice_group_idc` shall be in the range of 0 to 2, inclusive.

D.2.8 Decoded reference picture marking repetition SEI message semantics

The decoded reference picture marking repetition SEI message is used to repeat the decoded reference picture marking syntax structure that was located in the slice header of an earlier picture in the sequence in decoding order.

original_idr_flag shall be equal to 1 when the decoded reference picture marking syntax structure occurred originally in an IDR picture. `original_idr_flag` shall be equal to 0 when the repeated decoded reference picture marking syntax structure did not occur in an IDR picture originally.

original_frame_num shall be equal to the frame_num of the picture where the repeated decoded reference picture marking syntax structure originally occurred. The picture indicated by original_frame_num is the previous coded picture having the specified value of frame_num. The value of original_frame_num used to refer to a picture having a memory_management_control_operation equal to 5 shall be 0.

original_field_pic_flag shall be equal to the field_pic_flag of the picture where the repeated decoded reference picture marking syntax structure originally occurred.

original_bottom_field_flag shall be equal to the bottom_field_flag of the picture where the repeated decoded reference picture marking syntax structure originally occurred.

dec_ref_pic_marking() shall contain a copy of the decoded reference picture marking syntax structure of the picture whose frame_num was original_frame_num. The nal_unit_type used for specification of the repeated dec_ref_pic_marking() syntax structure shall be the nal_unit_type of the slice header(s) of the picture whose frame_num was original_frame_num (i.e., nal_unit_type as used in subclause 7.3.3.3 shall be considered equal to 5 when original_idr_flag is equal to 1 and shall not be considered equal to 5 when original_idr_flag is equal to 0).

D.2.9 Spare picture SEI message semantics

This SEI message indicates that certain slice group map units, called spare slice group map units, in one or more decoded reference pictures resemble the co-located slice group map units in a specified decoded picture called the target picture. A spare slice group map unit may be used to replace a co-located, incorrectly decoded slice group map unit, in the target picture. A decoded picture containing spare slice group map units is called a spare picture.

For all spare pictures identified in a spare picture SEI message, the value of frame_mbs_only_flag shall be equal to the value of frame_mbs_only_flag of the target picture in the same SEI message. The spare pictures in the SEI message are constrained as follows.

- If the target picture is a decoded field, all spare pictures identified in the same SEI message shall be decoded fields.
- Otherwise (the target picture is a decoded frame), all spare pictures identified in the same SEI message shall be decoded frames.

For all spare pictures identified in a spare picture SEI message, the values of pic_width_in_mbs_minus1 and pic_height_in_map_units_minus1 shall be equal to the values of pic_width_in_mbs_minus1 and pic_height_in_map_units_minus1, respectively, of the target picture in the same SEI message. The picture associated (as specified in subclause 7.4.1.2.3) with this message shall appear after the target picture, in decoding order.

target_frame_num indicates the frame_num of the target picture.

spare_field_flag equal to 0 indicates that the target picture and the spare pictures are decoded frames. spare_field_flag equal to 1 indicates that the target picture and the spare pictures are decoded fields.

target_bottom_field_flag equal to 0 indicates that the target picture is a top field. target_bottom_field_flag equal to 1 indicates that the target picture is a bottom field.

A target picture is a decoded reference picture whose corresponding primary coded picture precedes the current picture, in decoding order, and in which the values of frame_num, field_pic_flag (when present) and bottom_field_flag (when present) are equal to target_frame_num, spare_field_flag and target_bottom_field_flag, respectively.

num_spare_pics_minus1 indicates the number of spare pictures for the specified target picture. The number of spare pictures is equal to num_spare_pics_minus1 + 1. The value of num_spare_pics_minus1 shall be in the range of 0 to 15, inclusive.

delta_spare_frame_num[i] is used to identify the spare picture that contains the i-th set of spare slice group map units, hereafter called the i-th spare picture, as specified below. The value of delta_spare_frame_num[i] shall be in the range of 0 to MaxFrameNum - 1 - !spare_field_flag, inclusive.

The frame_num of the i-th spare picture, spareFrameNum[i], is derived as follows for all values of i from 0 to num_spare_pics_minus1, inclusive:

```
candidateSpareFrameNum = target_frame_num - !spare_field_flag
for ( i = 0; i <= num_spare_pics_minus1; i++ ) {
    if( candidateSpareFrameNum < 0 )
        candidateSpareFrameNum = MaxFrameNum - 1
    spareFrameNum[ i ] = candidateSpareFrameNum - delta_spare_frame_num[ i ]
    if( spareFrameNum[ i ] < 0 )
        spareFrameNum[ i ] = MaxFrameNum + spareFrameNum[ i ]
}
```

(D-3)

```

candidateSpareFrameNum = spareFrameNum[ i ] - !spare_field_flag
}

```

spare_bottom_field_flag[i] equal to 0 indicates that the i-th spare picture is a top field. **spare_bottom_field_flag[i]** equal to 1 indicates that the i-th spare picture is a bottom field.

The 0-th spare picture is a decoded reference picture whose corresponding primary coded picture precedes the target picture, in decoding order, and in which the values of **frame_num**, **field_pic_flag** (when present) and **bottom_field_flag** (when present) are equal to **spareFrameNum[0]**, **spare_field_flag** and **spare_bottom_field_flag[0]**, respectively. The i-th spare picture is a decoded reference picture whose corresponding primary coded picture precedes the (i - 1)-th spare picture, in decoding order, and in which the values of **frame_num**, **field_pic_flag** (when present) and **bottom_field_flag** (when present) are equal to **spareFrameNum[i]**, **spare_field_flag** and **spare_bottom_field_flag[i]**, respectively.

spare_area_idc[i] indicates the method used to identify the spare slice group map units in the i-th spare picture. **spare_area_idc[i]** shall be in the range of 0 to 2, inclusive. **spare_area_idc[i]** equal to 0 indicates that all slice group map units in the i-th spare picture are spare units. **spare_area_idc[i]** equal to 1 indicates that the value of the syntax element **spare_unit_flag[i][j]** is used to identify the spare slice group map units. **spare_area_idc[i]** equal to 2 indicates that the **zero_run_length[i][j]** syntax element is used to derive the values of **spareUnitFlagInBoxOutOrder[i][j]**, as described below.

spare_unit_flag[i][j] equal to 0 indicates that the j-th slice group map unit in raster scan order in the i-th spare picture is a spare unit. **spare_unit_flag[i][j]** equal to 1 indicates that the j-th slice group map unit in raster scan order in the i-th spare picture is not a spare unit.

zero_run_length[i][j] is used to derive the values of **spareUnitFlagInBoxOutOrder[i][j]** when **spare_area_idc[i]** is equal to 2. In this case, the spare slice group map units identified in **spareUnitFlagInBoxOutOrder[i][j]** appear in counter-clockwise box-out order, as specified in subclause 8.2.2.4, for each spare picture. **spareUnitFlagInBoxOutOrder[i][j]** equal to 0 indicates that the j-th slice group map unit in counter-clockwise box-out order in the i-th spare picture is a spare unit. **spareUnitFlagInBoxOutOrder[i][j]** equal to 1 indicates that the j-th slice group map unit in counter-clockwise box-out order in the i-th spare picture is not a spare unit.

When **spare_area_idc[0]** is equal to 2, **spareUnitFlagInBoxOutOrder[0][j]** is derived as follows:

```

for( j = 0, loop = 0; j < PicSizeInMapUnits; loop++ ) {
    for( k = 0; k < zero_run_length[ 0 ][ loop ]; k++ )
        spareUnitFlagInBoxOutOrder[ 0 ][ j++ ] = 0
        spareUnitFlagInBoxOutOrder[ 0 ][ j++ ] = 1
}

```

(D-4)

When **spare_area_idc[i]** is equal to 2 and the value of i is greater than 0, **spareUnitFlagInBoxOutOrder[i][j]** is derived as follows:

```

for( j = 0, loop = 0; j < PicSizeInMapUnits; loop++ ) {
    for( k = 0; k < zero_run_length[ i ][ loop ]; k++ )
        spareUnitFlagInBoxOutOrder[ i ][ j ] = spareUnitFlagInBoxOutOrder[ i - 1 ][ j++ ]
        spareUnitFlagInBoxOutOrder[ i ][ j ] = !spareUnitFlagInBoxOutOrder[ i - 1 ][ j++ ]
}

```

(D-5)

D.2.10 Scene information SEI message semantics

A scene and a scene transition are herein defined as a set of consecutive pictures in output order.

NOTE 1 – Decoded pictures within one scene generally have similar content. The scene information SEI message is used to label pictures with scene identifiers and to indicate scene changes. The message specifies how the source pictures for the labelled pictures were created. The decoder may use the information to select an appropriate algorithm to conceal transmission errors. For example, a specific algorithm may be used to conceal transmission errors that occurred in pictures belonging to a gradual scene transition. Furthermore, the scene information SEI message may be used in a manner determined by the application, such as for indexing the scenes of a coded sequence.

A scene information SEI message labels all pictures, in decoding order, from the primary coded picture to which the SEI message is associated (inclusive), as specified in subclause 7.4.1.2.3, to the primary coded picture to which the next scene information SEI message (if present) in decoding order is associated (exclusive) or (otherwise) to the last access unit in the bitstream (inclusive). These pictures are herein referred to as the target pictures.

scene_info_present_flag equal to 0 indicates that the scene or scene transition to which the target pictures belong is unspecified. **scene_info_present_flag** equal to 1 indicates that the target pictures belong to the same scene or scene transition.

scene_id identifies the scene to which the target pictures belong. When the value of **scene_transition_type** of the target pictures is less than 4, and the previous picture in output order is marked with a value of **scene_transition_type** less than 4, and the value of **scene_id** is the same as the value of **scene_id** of the previous picture in output order, this indicates that the source scene for the target pictures and the source scene for the previous picture (in output order) are considered by the encoder to have been the same scene. When the value of **scene_transition_type** of the target pictures is greater than 3, and the previous picture in output order is marked with a value of **scene_transition_type** less than 4, and the value of **scene_id** is the same as the value of **scene_id** of the previous picture in output order, this indicates that one of the source scenes for the target pictures and the source scene for the previous picture (in output order) are considered by the encoder to have been the same scene. When the value of **scene_id** is not equal to the value of **scene_id** of the previous picture in output order, this indicates that the target pictures and the previous picture (in output order) are considered by the encoder to have been from different source scenes.

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

scene_transition_type specifies in which type of a scene transition (if any) the target pictures are involved. The valid values of **scene_transition_type** are specified in Table D-4.

Table D-4 – scene_transition_type values

Value	Description
0	No transition
1	Fade to black
2	Fade from black
3	Unspecified transition from or to constant colour
4	Dissolve
5	Wipe
6	Unspecified mixture of two scenes

When **scene_transition_type** is greater than 3, the target pictures include contents both from the scene labelled by its **scene_id** and the next scene, in output order, which is labelled by **second_scene_id** (see below). The term “the current scene” is used to indicate the scene labelled by **scene_id**. The term “the next scene” is used to indicate the scene labelled by **second_scene_id**. It is not required for any following picture, in output order, to be labelled with **scene_id** equal to **second_scene_id** of the current SEI message.

Scene transition types are specified as follows.

“No transition” specifies that the target pictures are not involved in a gradual scene transition.

NOTE 2 – When two consecutive pictures in output order have **scene_transition_type** equal to 0 and different values of **scene_id**, a scene cut occurred between the two pictures.

“Fade to black” indicates that the target pictures are part of a sequence of pictures, in output order, involved in a fade to black scene transition, i.e., the luma samples of the scene gradually approach zero and the chroma samples of the scene gradually approach 128.

NOTE 3 – When two pictures are labelled to belong to the same scene transition and their **scene_transition_type** is "Fade to black", the later one, in output order, is darker than the previous one.

“Fade from black” indicates that the target pictures are part of a sequence of pictures, in output order, involved in a fade from black scene transition, i.e., the luma samples of the scene gradually diverge from zero and the chroma samples of the scene may gradually diverge from 128.

NOTE 4 – When two pictures are labelled to belong to the same scene transition and their **scene_transition_type** is "Fade from black", the later one in output order is lighter than the previous one.

“Dissolve” indicates that the sample values of each target picture (before encoding) were generated by calculating a sum of co-located weighted sample values of a picture from the current scene and a picture from the next scene. The

weight of the current scene gradually decreases from full level to zero level, whereas the weight of the next scene gradually increases from zero level to full level. When two pictures are labelled to belong to the same scene transition and their `scene_transition_type` is "Dissolve", the weight of the current scene for the later one, in output order, is less than the weight of the current scene for the previous one, and the weight of the next scene for the later one, in output order, is greater than the weight of the next scene for the previous one.

"Wipe" indicates that some of the sample values of each target picture (before encoding) were generated by copying co-located sample values of a picture in the current scene and the remaining sample values of each target picture (before encoding) were generated by copying co-located sample values of a picture in the next scene. When two pictures are labelled to belong to the same scene transition and their `scene_transition_type` is "Wipe", the number of samples copied from the next scene to the later picture in output order is greater than the number of samples copied from the next scene to the previous picture.

second_scene_id identifies the next scene in the gradual scene transition in which the target pictures are involved. The value of `second_scene_id` shall not be equal to the value of `scene_id`. The value of `second_scene_id` shall not be equal to the value of `scene_id` in the previous picture in output order. When the next picture in output order is marked with a value of `scene_transition_type` less than 4, and the value of `second_scene_id` is the same as the value of `scene_id` of the next picture in output order, this indicates that the encoder considers one of the source scenes for the target pictures and the source scene for the next picture (in output order) to have been the same scene. When the value of `second_scene_id` is not equal to the value of `scene_id` or `second_scene_id` (if present) of the next picture in output order, this indicates that the encoder considers the target pictures and the next picture (in output order) to have been from different source scenes.

When the value of `scene_id` of a picture is equal to the value of `scene_id` of the following picture in output order and the value of `scene_transition_type` in both of these pictures is less than 4, this indicates that the encoder considers the two pictures to have been from the same source scene. When the values of `scene_id`, `scene_transition_type` and `second_scene_id` (if present) of a picture are equal to the values of `scene_id`, `scene_transition_type` and `second_scene_id` (respectively) of the following picture in output order and the value of `scene_transition_type` is greater than 0, this indicates that the encoder considers the two pictures to have been from the same source gradual scene transition.

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

D.2.11 Sub-sequence information SEI message semantics

The sub-sequence information SEI message is used to indicate the position of a picture in data dependency hierarchy that consists of sub-sequence layers and sub-sequences.

A sub-sequence layer contains a subset of the coded pictures in a sequence. Sub-sequence layers are numbered with non-negative integers. A layer having a larger layer number is a higher layer than a layer having a smaller layer number. The layers are ordered hierarchically based on their dependency on each other so that any picture in a layer shall not be predicted from any picture on any higher layer.

NOTE 1 – In other words, any picture in layer 0 must not be predicted from any picture in layer 1 or above, pictures in layer 1 may be predicted from layer 0, pictures in layer 2 may be predicted from layers 0 and 1, etc.

NOTE 2 – The subjective quality is expected to increase along with the number of decoded layers.

A sub-sequence is a set of coded pictures within a sub-sequence layer. A picture shall reside in one sub-sequence layer and in one sub-sequence only. Any picture in a sub-sequence shall not be predicted from any picture in another sub-sequence in the same or in a higher sub-sequence layer. A sub-sequence in layer 0 can be decoded independently of any picture that does not belong to the sub-sequence.

The sub-sequence information SEI message concerns the current access unit. The primary coded picture in the access unit is herein referred to as the current picture.

The sub-sequence information SEI message shall not be present unless `gaps_in_frame_num_value_allowed_flag` in the sequence parameter set referenced by the picture associated with the sub-sequence SEI message is equal to 1.

sub_seq_layer_num specifies the sub-sequence layer number of the current picture. When `sub_seq_layer_num` is greater than 0, memory management control operations shall not be used in any slice header of the current picture. When the current picture resides in a sub-sequence whose first picture in decoding order is an IDR picture, the value of `sub_seq_layer_num` shall be equal to 0. For a non-paired reference field, the value of `sub_seq_layer_num` shall be equal to 0. `sub_seq_layer_num` shall be in the range of 0 to 255, inclusive.

sub_seq_id identifies the sub-sequence within a layer. When the current picture resides in a sub-sequence whose first picture in decoding order is an IDR picture, the value of **sub_seq_id** shall be the same as the value of **idr_pic_id** of the IDR picture. **sub_seq_id** shall be in the range of 0 to 65535, inclusive.

first_ref_pic_flag equal to 1 specifies that the current picture is the first reference picture of the sub-sequence in decoding order. When the current picture is not the first picture of the sub-sequence in decoding order, the **first_ref_pic_flag** shall be equal to 0.

leading_non_ref_pic_flag equal to 1 specifies that the current picture is a non-reference picture preceding any reference picture in decoding order within the sub-sequence or that the sub-sequence contains no reference pictures. When the current picture is a reference picture or the current picture is a non-reference picture succeeding at least one reference picture in decoding order within the sub-sequence, the **leading_non_ref_pic_flag** shall be equal to 0.

last_pic_flag equal to 1 indicates that the current picture is the last picture of the sub-sequence (in decoding order), including all reference and non-reference pictures of the sub-sequence. When the current picture is not the last picture of the sub-sequence (in decoding order), **last_pic_flag** shall be equal to 0.

The current picture is assigned to a sub-sequence as follows.

- If one or more of the following conditions is true, the current picture is the first picture of a sub-sequence in decoding order.
 - no earlier picture in decoding order is labelled with the same values of **sub_seq_id** and **sub_seq_layer_num** as the current picture
 - the value of **leading_non_ref_pic_flag** is equal to 1 and the value of **leading_non_ref_pic_flag** is equal to 0 in the previous picture in decoding order having the same values of **sub_seq_id** and **sub_seq_layer_num** as the current picture
 - the value of **first_ref_pic_flag** is equal to 1 and the value of **leading_non_ref_pic_flag** is equal to 0 in the previous picture in decoding order having the same values of **sub_seq_id** and **sub_seq_layer_num** as the current picture
 - the value of **last_pic_flag** is equal to 1 in the previous picture in decoding order having the same values of **sub_seq_id** and **sub_seq_layer_num** as the current picture
- Otherwise, the current picture belongs to the same sub-sequence as the previous picture in decoding order having the same values of **sub_seq_id** and **sub_seq_layer_num** as the current picture.

sub_seq_frame_num_flag equal to 0 specifies that **sub_seq_frame_num** is not present. **sub_seq_frame_num_flag** equal to 1 specifies that **sub_seq_frame_num** is present.

sub_seq_frame_num shall be equal to 0 for the first reference picture of the sub-sequence and for any non-reference picture preceding the first reference picture of the sub-sequence in decoding order. **sub_seq_frame_num** is further constrained as follows.

- If the current picture is not the second field of a complementary field pair, **sub_seq_frame_num** shall be incremented by 1, in modulo **MaxFrameNum** operation, relative to the previous reference picture, in decoding order, that belongs to the sub-sequence.
- Otherwise (the current picture is the second field of a complementary field pair), the value of **sub_seq_frame_num** shall be the same as the value of **sub_seq_frame_num** for the first field of the complementary field pair.

sub_seq_frame_num shall be in the range of 0 to **MaxFrameNum** – 1, inclusive.

When the current picture is an IDR picture, it shall start a new sub-sequence in sub-sequence layer 0. Thus, the **sub_seq_layer_num** shall be 0, the **sub_seq_id** shall be different from the previous sub-sequence in sub-sequence layer 0, **first_ref_pic_flag** shall be 1, and **leading_non_ref_pic_flag** shall be equal to 0.

When the sub-sequence information SEI message is present for both coded fields of a complementary field pair, the values of **sub_seq_layer_num**, **sub_seq_id**, **leading_non_ref_pic_flag** and **sub_seq_frame_num**, when present, shall be identical for both of these pictures.

When the sub-sequence information SEI message is present only for one coded field of a complementary field pair, the values of **sub_seq_layer_num**, **sub_seq_id**, **leading_non_ref_pic_flag** and **sub_seq_frame_num**, when present, are also applicable to the other coded field of the complementary field pair.

D.2.12 Sub-sequence layer characteristics SEI message semantics

The sub-sequence layer characteristics SEI message specifies the characteristics of sub-sequence layers.

num_sub_seq_layers_minus1 plus 1 specifies the number of sub-sequence layers in the sequence. **num_sub_seq_layers_minus1** shall be in the range of 0 to 255, inclusive.

A pair of **average_bit_rate** and **average_frame_rate** characterizes each sub-sequence layer. The first pair of **average_bit_rate** and **average_frame_rate** specifies the characteristics of sub-sequence layer 0. When present, the second pair specifies the characteristics of sub-sequence layers 0 and 1 jointly. Each pair in decoding order specifies the characteristics for a range of sub-sequence layers from layer number 0 to the layer number specified by the layer loop counter. The values are in effect from the point they are decoded until an update of the values is decoded.

accurate_statistics_flag equal to 1 indicates that the values of **average_bit_rate** and **average_frame_rate** are rounded from statistically correct values. **accurate_statistics_flag** equal to 0 indicates that the **average_bit_rate** and the **average_frame_rate** are estimates and may deviate somewhat from the correct values.

When **accurate_statistics_flag** is equal to 0, the quality of the approximation used in the computation of the values of **average_bit_rate** and the **average_frame_rate** is chosen by the encoding process and is not specified by this Recommendation | International Standard.

average_bit_rate indicates the average bit rate in units of 1000 bits per second. All NAL units in the range of sub-sequence layers specified above are taken into account in the calculation. The average bit rate is derived according to the access unit removal time specified in Annex C of the Recommendation | International Standard. In the following, **bTotal** is the number of bits in all NAL units succeeding a sub-sequence layer characteristics SEI message (including the bits of the NAL units of the current access unit) and preceding the next access unit (in decoding order) including a sub-sequence layer characteristics SEI message (if present) or the end of the stream (otherwise). t_1 is the removal time (in seconds) of the current access unit, and t_2 is the removal time (in seconds) of the latest access unit (in decoding order) before the next sub-sequence layer characteristics SEI message (if present) or the end of the stream (otherwise).

When **accurate_statistics_flag** is equal to 1, the following conditions shall be fulfilled as follows.

- If t_1 is not equal to t_2 , the following condition shall be true

$$\text{average_bit_rate} == \text{Round}(\text{bTotal} \div ((t_2 - t_1) * 1000)) \quad (\text{D-6})$$

- Otherwise (t_1 is equal to t_2), the following condition shall be true

$$\text{average_bit_rate} == 0 \quad (\text{D-7})$$

average_frame_rate indicates the average frame rate in units of frames/(256 seconds). All NAL units in the range of sub-sequence layers specified above are taken into account in the calculation. In the following, **fTotal** is the number of frames, complementary field pairs and non-paired fields between the current picture (inclusive) and the next sub-sequence layer characteristics SEI message (if present) or the end of the stream (otherwise). t_1 is the removal time (in seconds) of the current access unit, and t_2 is the removal time (in seconds) of the latest access unit (in decoding order) before the next sub-sequence layer characteristics SEI message (if present) or the end of the stream (otherwise).

When **accurate_statistics_flag** is equal to 1, the following conditions shall be fulfilled as follows.

- If t_1 is not equal to t_2 , the following condition shall be true

$$\text{average_frame_rate} == \text{Round}(\text{fTotal} * 256 \div (t_2 - t_1)) \quad (\text{D-8})$$

- Otherwise (t_1 is equal to t_2), the following condition shall be true

$$\text{average_frame_rate} == 0 \quad (\text{D-9})$$

D.2.13 Sub-sequence characteristics SEI message semantics

The sub-sequence characteristics SEI message indicates the characteristics of a sub-sequence. It also indicates inter prediction dependencies between sub-sequences. This message shall be contained in the first access unit in decoding order of the sub-sequence to which the sub-sequence characteristics SEI message applies. This sub-sequence is herein called the target sub-sequence.

sub_seq_layer_num identifies the sub-sequence layer number of the target sub-sequence. **sub_seq_layer_num** shall be in the range of 0 to 255, inclusive.

sub_seq_id identifies the target sub-sequence. **sub_seq_id** shall be in the range of 0 to 65535, inclusive.

duration_flag equal to 0 indicates that the duration of the target sub-sequence is not specified.

sub_seq_duration specifies the duration of the target sub-sequence in clock ticks of a 90-kHz clock.

average_rate_flag equal to 0 indicates that the average bit rate and the average frame rate of the target sub-sequence are unspecified.

accurate_statistics_flag indicates how reliable the values of **average_bit_rate** and **average_frame_rate** are. **accurate_statistics_flag** equal to 1, indicates that the **average_bit_rate** and the **average_frame_rate** are rounded from statistically correct values. **accurate_statistics_flag** equal to 0 indicates that the **average_bit_rate** and the **average_frame_rate** are estimates and may deviate from the statistically correct values.

average_bit_rate indicates the average bit rate in (1000 bits)/second of the target sub-sequence. All NAL units of the target sub-sequence are taken into account in the calculation. The average bit rate is derived according to the access unit removal time specified in subclause C.1.2. In the following, nB is the number of bits in all NAL units in the sub-sequence. t_1 is the removal time (in seconds) of the first access unit of the sub-sequence (in decoding order), and t_2 is the removal time (in seconds) of the last access unit of the sub-sequence (in decoding order).

When **accurate_statistics_flag** is equal to 1, the following conditions shall be fulfilled as follows.

- If t_1 is not equal to t_2 , the following condition shall be true

$$\text{average_bit_rate} == \text{Round}(nB \div ((t_2 - t_1) * 1000)) \quad (\text{D-10})$$

- Otherwise (t_1 is equal to t_2), the following condition shall be true

$$\text{average_bit_rate} == 0 \quad (\text{D-11})$$

average_frame_rate indicates the average frame rate in units of frames/(256 seconds) of the target sub-sequence. All NAL units of the target sub-sequence are taken into account in the calculation. The average frame rate is derived according to the access unit removal time specified in subclause C.1.2. In the following, fC is the number of frames, complementary field pairs and non-paired fields in the sub-sequence. t_1 is the removal time (in seconds) of the first access unit of the sub-sequence (in decoding order), and t_2 is the removal time (in seconds) of the last access unit of the sub-sequence (in decoding order).

When **accurate_statistics_flag** is equal to 1, the following conditions shall be fulfilled as follows.

- If t_1 is not equal to t_2 , the following condition shall be true

$$\text{average_frame_rate} == \text{Round}(fC * 256 \div (t_2 - t_1)) \quad (\text{D-12})$$

- Otherwise (t_1 is equal to t_2), the following condition shall be true

$$\text{average_frame_rate} == 0 \quad (\text{D-13})$$

num_referenced_subseqs specifies the number of sub-sequences that contain pictures that are used as reference pictures for inter prediction in the pictures of the target sub-sequence. **num_referenced_subseqs** shall be in the range of 0 to 255, inclusive.

ref_sub_seq_layer_num, **ref_sub_seq_id**, and **ref_sub_seq_direction** identify the sub-sequence that contains pictures that are used as reference pictures for inter prediction in the pictures of the target sub-sequence. Depending on **ref_sub_seq_direction**, the following applies.

- If **ref_sub_seq_direction** is equal to 0, a set of candidate sub-sequences consists of the sub-sequences whose **sub_seq_id** is equal to **ref_sub_seq_id**, which reside in the sub-sequence layer having **sub_seq_layer_num** equal to **ref_sub_seq_layer_num**, and whose first picture in decoding order precedes the first picture of the target sub-sequence in decoding order.
- Otherwise (**ref_sub_seq_direction** is equal to 1), a set of candidate sub-sequences consists of the sub-sequences whose **sub_seq_id** is equal to **ref_sub_seq_id**, which reside in the sub-sequence layer having **sub_seq_layer_num** equal to **ref_sub_seq_layer_num**, and whose first picture in decoding order succeeds the first picture of the target sub-sequence in decoding order.

The sub-sequence used as a reference for the target sub-sequence is the sub-sequence among the set of candidate sub-sequences whose first picture is the closest to the first picture of the target sub-sequence in decoding order.

D.2.14 Full-frame freeze SEI message semantics

The full-frame freeze SEI message indicates that the current picture and any subsequent pictures in output order that meet specified conditions should not affect the content of the display. No more than one full-frame freeze SEI message shall be present in any access unit.

full_frame_freeze_repetition_period specifies the persistence of the full-frame freeze SEI message and may specify a picture order count interval within which another full-frame freeze SEI message or a full-frame freeze release SEI or the end of the coded video sequence shall be present in the bitstream. The value of **full_frame_freeze_repetition_period** shall be in the range of 0 to 16 384, inclusive.

full_frame_freeze_repetition_period equal to 0 specifies that the full-frame freeze SEI message applies to the current decoded picture only.

full_frame_freeze_repetition_period equal to 1 specifies that the full-frame freeze SEI message persists in output order until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a full-frame freeze SEI message or a full-frame freeze release SEI message is output having **PicOrderCnt()** greater than **PicOrderCnt(CurrPic)**.

full_frame_freeze_repetition_period greater than 1 specifies that the full-frame freeze SEI message persists until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a full-frame freeze SEI message or a full-frame freeze release SEI message is output having **PicOrderCnt()** greater than **PicOrderCnt(CurrPic)** and less than or equal to **PicOrderCnt(CurrPic) + full_frame_freeze_repetition_period**.

full_frame_freeze_repetition_period greater than 1 indicates that another full-frame freeze SEI message or a full-frame freeze release SEI message shall be present for a picture in an access unit that is output having **PicOrderCnt()** greater than **PicOrderCnt(CurrPic)** and less than or equal to **PicOrderCnt(CurrPic) + full_frame_freeze_repetition_period**; unless the bitstream ends or a new coded video sequence begins without output of such a picture.

D.2.15 Full-frame freeze release SEI message semantics

The full-frame freeze release SEI message cancels the effect of any full-frame freeze SEI message sent with pictures that precede the current picture in output order. The full-frame freeze release SEI message indicates that the current picture and subsequent pictures in output order should affect the contents of the display.

No more than one full-frame freeze release SEI message shall be present in any access unit. A full-frame freeze release SEI message shall not be present in an access unit containing a full-frame freeze SEI message. When a full-frame freeze SEI message is present in an access unit containing a field of a complementary field pair in which the values of **PicOrderCnt(CurrPic)** for the two fields of the complementary field pair are equal to each other, a full-frame freeze release SEI message shall not be present in either of the two access units.

D.2.16 Full-frame snapshot SEI message semantics

The full-frame snapshot SEI message indicates that the current frame is labelled for use as determined by the application as a still-image snapshot of the video content.

snapshot_id specifies a snapshot identification number. **snapshot_id** shall be in the range of 0 to $2^{32} - 1$, inclusive.

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

D.2.17 Progressive refinement segment start SEI message semantics

The progressive refinement segment start SEI message specifies the beginning of a set of consecutive coded pictures that is labelled as the current picture followed by a sequence of one or more pictures of refinement of the quality of the current picture, rather than as a representation of a continually moving scene.

The tagged set of consecutive coded pictures shall continue until one of the following conditions is true. When a condition below becomes true, the next slice to be decoded does not belong to the tagged set of consecutive coded pictures.

1. The next slice to be decoded belongs to an IDR picture.

2. `num_refinement_steps_minus1` is greater than 0 and the `frame_num` of the next slice to be decoded is $(\text{currFrameNum} + \text{num_refinement_steps_minus1} + 1) \% \text{MaxFrameNum}$, where `currFrameNum` is the value of `frame_num` of the picture in the access unit containing the SEI message.
3. `num_refinement_steps_minus1` is 0 and a progressive refinement segment end SEI message with the same `progressive_refinement_id` as the one in this SEI message is decoded.

The decoding order of picture within the tagged set of consecutive pictures should be the same as their output order. **progressive_refinement_id** specifies an identification number for the progressive refinement operation. `progressive_refinement_id` shall be in the range of 0 to $2^{32} - 1$, inclusive.

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

num_refinement_steps_minus1 specifies the number of reference frames in the tagged set of consecutive coded pictures as follows.

- If `num_refinement_steps_minus1` is equal to 0, the number of reference frames in the tagged set of consecutive coded pictures is unknown.
- Otherwise, the number of reference frames in the tagged set of consecutive coded pictures is equal to `num_refinement_steps_minus1 + 1`.

`num_refinement_steps_minus1` shall be in the range of 0 to `MaxFrameNum - 1`, inclusive.

D.2.18 Progressive refinement segment end SEI message semantics

The progressive refinement segment end SEI message specifies the end of a set of consecutive coded pictures that has been labelled by use of a progressive refinement segment start SEI message as an initial picture followed by a sequence of one or more pictures of the refinement of the quality of the initial picture, and ending with the current picture.

progressive_refinement_id specifies an identification number for the progressive refinement operation. `progressive_refinement_id` shall be in the range of 0 to $2^{32} - 1$, inclusive.

The progressive refinement segment end SEI message specifies the end of any progressive refinement segment previously started using a progressive refinement segment start SEI message with the same value of `progressive_refinement_id`.

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

D.2.19 Motion-constrained slice group set SEI message semantics

This SEI message indicates that inter prediction over slice group boundaries is constrained as specified below. When present, the message shall only appear where it is associated, as specified in subclause 7.4.1.2.3, with an IDR access unit.

The target picture set for this SEI message contains all consecutive primary coded pictures in decoding order starting with the associated primary coded IDR picture (inclusive) and ending with the following primary coded IDR picture (exclusive) or with the very last primary coded picture in the bitstream (inclusive) in decoding order when there is no following primary coded IDR picture. The slice group set is a collection of one or more slice groups, identified by the `slice_group_id[i]` syntax element.

This SEI message indicates that, for each picture in the target picture set, the inter prediction process is constrained as follows: No sample value outside the slice group set, and no sample value at a fractional sample position that is derived using one or more sample values outside the slice group set is used to inter predict any sample within the slice group set.

num_slice_groups_in_set_minus1 + 1 specifies the number of slice groups in the slice group set. The allowed range of `num_slice_groups_in_set_minus1` is 0 to `num_slice_groups_minus1`, inclusive. The allowed range of `num_slice_groups_minus1` is specified in Annex A.

slice_group_id[i] identifies the slice group(s) contained within the slice group set. The allowed range is from 0 to num_slice_groups_in_set_minus1, inclusive. The size of the slice_group_id[i] syntax element is $\text{Ceil}(\text{Log}_2(\text{num_slice_groups_minus1} + 1))$ bits.

exact_sample_value_match_flag equal to 0 indicates that, within the target picture set, when the macroblocks that do not belong to the slice group set are not decoded, the value of each sample in the slice group set need not be exactly the same as the value of the same sample when all the macroblocks are decoded. exact_sample_value_match_flag equal to 1 indicates that, within the target picture set, when the macroblocks that do not belong to the slice group set are not decoded, the value of each sample in the slice group set shall be exactly the same as the value of the same sample when all the macroblocks in the target picture set are decoded.

NOTE 1 – When disable_deblocking_filter_idc is equal to 2 in all slices in the target picture set, exact_sample_value_match_flag should be 1.

pan_scan_rect_flag equal to 0 specifies that pan_scan_rect_id is not present. pan_scan_rect_flag equal to 1 specifies that pan_scan_rect_id is present.

pan_scan_rect_id indicates that the specified slice group set covers at least the pan-scan rectangle identified by pan_scan_rect_id within the target picture set.

NOTE 2 – Multiple motion_constrained_slice_group_set SEI messages may be associated with the same IDR picture. Consequently, more than one slice group set may be active within a target picture set.

NOTE 3 – The size, shape, and location of the slice groups in the slice group set may change within the target picture set.

D.2.20 Film grain characteristics SEI message semantics

This SEI message provides the decoder with a parameterised model for film grain synthesis. For example, an encoder may use the film grain characteristics SEI message to characterise film grain that was present in the original source video material and was removed by pre-processing filtering techniques. Synthesis of simulated film grain on the decoded images for the display process is optional and does not affect the decoding process specified in this Recommendation | International Standard. If synthesis of simulated film grain on the decoded images for the display process is performed, there is no requirement that the method by which the synthesis is performed be the same as the parameterised model for the film grain as provided in the film grain characteristics SEI message.

NOTE 1 – The display process is not specified in this Recommendation | International Standard.

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

model_id identifies the film grain simulation model as specified in Table D-5. The value of model_id shall be in the range of 0 to 1, inclusive.

Table D-5 – model_id values

Value	Description
0	frequency filtering
1	auto-regression
2	reserved
3	reserved

separate_colour_description_present_flag equal to 1 indicates that a distinct colour space description for the film grain characteristics specified in the SEI message is present in the film grain characteristics SEI message syntax. separate_colour_description_present_flag equal to 0 indicates that the colour description for the film grain characteristics specified in the SEI message is the same as for the coded video sequence as specified in subclause E.2.1.

NOTE 2 – When separate_colour_description_present_flag is equal to 1, the colour space specified for the film grain characteristics specified in the SEI message may differ from the colour space specified for the coded video as specified in subclause E.2.1.

film_grain_bit_depth_luma_minus8 plus 8 specifies the bit depth used for the luma component of the film grain characteristics specified in the SEI message. When film_grain_bit_depth_luma_minus8 is not present in the film grain characteristics SEI message, the value of film_grain_bit_depth_luma_minus8 shall be inferred to be equal to bit_depth_luma_minus8.

The value of filmGrainBitDepth[0] is derived as

$$\text{filmGrainBitDepth}[0] = \text{film_grain_bit_depth_luma_minus8} + 8 \quad (\text{D-14})$$

film_grain_bit_depth_chroma_minus8 plus 8 specifies the bit depth used for the Cb and Cr components of the film grain characteristics specified in the SEI message. When **film_grain_bit_depth_chroma_minus8** is not present in the film grain characteristics SEI message, the value of **film_grain_bit_depth_chroma_minus8** shall be inferred to be equal to **bit_depth_chroma_minus8**.

The value of **filmGrainBitDepth[c]** for $c = 1$ and 2 is derived as

$$\text{filmGrainBitDepth}[c] = \text{film_grain_bit_depth_chroma_minus8} + 8 \quad \text{with } c = 1, 2 \quad (\text{D-15})$$

film_grain_full_range_flag has the same semantics as specified in subclause E.2.1 for the **video_full_range_flag** syntax element, except as follows.

- **film_grain_full_range_flag** specifies the colour space of the film grain characteristics specified in the SEI message, rather than the colour space used for the coded video sequence.
- When **film_grain_full_range_flag** is not present in the film grain characteristics SEI message, the value of **film_grain_full_range_flag** shall be inferred to be equal to **video_full_range_flag**.

film_grain_colour_primaries has the same semantics as specified in subclause E.2.1 for the **colour_primaries** syntax element, except as follows.

- **film_grain_colour_primaries** specifies the colour space of the film grain characteristics specified in the SEI message, rather than the colour space used for the coded video sequence.
- When **film_grain_colour_primaries** is not present in the film grain characteristics SEI message, the value of **film_grain_colour_primaries** shall be inferred to be equal to **colour_primaries**.

film_grain_transfer_characteristics has the same semantics as specified in subclause E.2.1 for the **transfer_characteristics** syntax element, except as follows.

- **film_grain_transfer_characteristics** specifies the colour space of the film grain characteristics specified in the SEI message, rather than the colour space used for the coded video sequence.
- When **film_grain_transfer_characteristics** is not present in the film grain characteristics SEI message, the value of **film_grain_transfer_characteristics** shall be inferred to be equal to **transfer_characteristics**.

film_grain_matrix_coefficients has the same semantics as specified in subclause E.2.1 for the **matrix_coefficients** syntax element, except as follows.

- **film_grain_matrix_coefficients** specifies the colour space of the film grain characteristics specified in the SEI message, rather than the colour space used for the coded video sequence.
- When **film_grain_matrix_coefficients** is not present in the film grain characteristics SEI message, the value of **film_grain_matrix_coefficients** shall be inferred to be equal to **matrix_coefficients**.
- The values allowed for **film_grain_matrix_coefficients** are not constrained by the value of **chroma_format_idc**.

The **chroma_format_idc** of the film grain characteristics specified in the film grain characteristics SEI message shall be inferred to be equal to 3 (4:4:4).

NOTE 3 – Because the use of a specific method is not required for performing film grain generation function used by the display process, a decoder may, if desired, down-convert the model information for chroma in order to simulate film grain for other chroma formats (4:2:0 or 4:2:2) rather than up-converting the decoded video (using a method not specified by this Recommendation | International Standard) before performing film grain generation.

blending_mode_id identifies the blending mode used to blend the simulated film grain with the decoded images as specified in Table D-6. **blending_mode_id** shall be in the range of 0 to 1, inclusive.

Table D-6 – blending_mode_id values

Value	Description
0	additive
1	multiplicative
2	reserved
3	reserved

Depending on `blending_mode_id`, the blending mode is specified as follows

- If `blending_mode_id` is equal to 0 the blending mode is additive as specified by

$$I_{\text{grain}}[x, y, c] = \text{Clip3}(0, (1 \ll \text{filmGrainBitDepth}[c]) - 1, I_{\text{decoded}}[x, y, c] + G[x, y, c]) \quad (\text{D-16})$$

- Otherwise (`blending_mode_id` is equal to 1), the blending mode is multiplicative as specified by

$$I_{\text{grain}}[x, y, c] = \text{Clip3}(0, (1 \ll \text{filmGrainBitDepth}[c]) - 1, I_{\text{decoded}}[x, y, c] * (1 + G[x, y, c])) \quad (\text{D-17})$$

where $I_{\text{decoded}}[x, y, c]$ represents the sample value at coordinates x, y of the colour component c of the decoded image I_{decoded} , $G[x, y, c]$ is the simulated film grain value at the same position and colour component, and $\text{filmGrainBitDepth}[c]$ is the number of bits used for each sample in a fixed-length unsigned binary representation of the array $I_{\text{grain}}[x, y, c]$.

log2_scale_factor specifies a scale factor used in the film grain characterization equations.

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

num_intensity_intervals_minus1[c] plus 1 specifies the number of intensity intervals for which a specific set of model values has been estimated.

NOTE 4 – The intensity intervals may overlap in order to simulate multi-generational film grain.

num_model_values_minus1[c] plus 1 specifies the number of model values present for each intensity interval in which the film grain has been modelled. The value of **num_model_values_minus1**[c] shall be in the range of 0 to 5, inclusive.

intensity_interval_lower_bound[c][i] specifies the lower bound of the interval i of intensity levels for which the set of model values applies.

intensity_interval_upper_bound[c][i] specifies the upper bound of the interval i of intensity levels for which the set of model values applies.

Depending on `model_id`, the selection of the sets of model values is specified as follows.

- If `model_id` is equal to 0, the average value of each block b of 16x16 samples in I_{decoded} , referred as b_{avg} , is used to select the sets of model values with index $s[j]$ that apply to all the samples in the block:

```
for( i = 0, j = 0; i <= num_intensity_intervals_minus1; i++ )
    if( b_avg >= intensity_interval_lower_bound[ c ][ i ] && b_avg <= intensity_interval_upper_bound[ c ][ i ] ) {
        s[ j ] = i
        j++
    }
} \quad (\text{D-18})
```

- Otherwise (`model_id` is equal to 1), the sets of model values used to generate the film grain are selected for each sample value in I_{decoded} as follows:

```
for( i = 0, j = 0; i <= num_intensity_intervals_minus1; i++ )
    if( I_decoded[ x, y, c ] >= intensity_interval_lower_bound[ c ][ i ] &&
        I_decoded[ x, y, c ] <= intensity_interval_upper_bound[ c ][ i ] ) {
        s[ j ] = i
        j++
    }
} \quad (\text{D-19})
```

Samples that do not fall into any of the defined intervals are not modified by the grain generation function. Samples that fall into more than one interval will originate multi-generational grain. Multi-generational grain results from adding the grain computed independently for each intensity interval.

comp_model_value[c][i][j] represents each one of the model values present for the colour component c and the intensity interval i. The set of model values has different meaning depending on the value of model_id. The value of comp_model_value[c][i][j] shall be constrained as follows, and may be additionally constrained as specified elsewhere in this subclause.

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

Depending on model_id, the synthesis of the film grain is modelled as follows.

- If model_id is equal to 0, a frequency filtering model enables simulating the original film grain for $c = 0..2$, $x = 0..PicWidthInSamples_L$, and $y = 0..PicHeightInSamples_L$ as specified by:

$$\begin{aligned} G[x, y, c] &= (\text{comp_model_value}[c][s][0] * Q[x, y, c] + \text{comp_model_value}[c][s][5] * \\ G[x, y, c-1]) & \gg \log2_scale_factor \end{aligned} \quad (D-20)$$

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

NOTE 5 – A normalized Gaussian random value can be generated from two independent, uniformly distributed random values over the interval from 0 to 1 (and not equal to 0), denoted as uRv₀ and uRv₁, using the Box-Muller transformation specified by

$$\text{gaussRv}_{ij} = \sqrt{-2 * \text{Ln}(uRv_0)} * \text{Cos}(2 * \pi * uRv_1) \quad (D-21)$$

where Ln(x) is the natural logarithm of x (the base-e logarithm, where e is natural logarithm base constant 2.718 281 828...), Cos(x) is the trigonometric cosine function operating on an argument x in units of radians, and π is Archimedes' constant 3.141 592 653....

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

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

(D-22)

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

$$\text{IDCT16x16}(z) = r * z * r^T \quad (D-23)$$

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

$$r_{ij} = \frac{((i == 0) ? 1 : \sqrt{2})}{4} \text{Cos}\left(\frac{i * (2 * j + 1) * \pi}{32}\right) \quad (D-24)$$

where Cos(x) is the trigonometric cosine function operating on an argument x in units of radians and π is Archimedes' constant 3.141 592 653.

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

NOTE 6 – Coded model values are based on blocks of 16x16, but a decoder implementation may use other block sizes. For example, decoders implementing the IDCT on 8x8 blocks, should down-convert by a factor of two the set of coded model values comp_model_value[c][s][i] for i equal to 1..4.

NOTE 7 – To reduce the degree of visible blocks that can result from mosaicing the frequency-filtered blocks filteredRv, decoders may apply a low-pass filter to the boundaries between frequency-filtered blocks.

- Otherwise (model_id is equal to 1), an auto-regression model enables simulating the original film grain for $c = 0.2$, $x = 0.PicWidthInSamples_L$, and $y = 0.PicHeightInSamples_L$ as specified by

$$\begin{aligned}
 G[x, y, c] = & (comp_model_value[c][s][0] * n[x, y, c] + \\
 & comp_model_value[c][s][1] * (G[x-1, y, c] + ((comp_model_value[c][s][4] * G[x, y-1, c]) >> \\
 & \quad \log2_scale_factor)) + \\
 & comp_model_value[c][s][3] * (((comp_model_value[c][s][4] * G[x-1, y-1, c]) >> \\
 & \quad \log2_scale_factor) + G[x+1, y-1, c]) + \\
 & comp_model_value[c][s][5] * (G[x-2, y, c] + \\
 & \quad ((comp_model_value[c][s][4] * comp_model_value[c][s][4] * G[x, y-2, c]) >> \\
 & \quad \quad (2 * \log2_scale_factor))) + \\
 & comp_model_value[c][s][2] * G[x, y, c-1]) >> \log2_scale_factor
 \end{aligned} \tag{D-25}$$

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

- x is less than 0,
- y is less than 0,
- x is greater than or equal to $PicWidthInSamples_L$,
- c is less than 0.

comp_model_value[c][i][0] provides the first model value for the model as specified by model_id. **comp_model_value[c][i][0]** corresponds to the standard deviation of the Gaussian noise term in the generation functions specified in Equations D-20 through D-23.

comp_model_value[c][i][1] provides the second model value for the model as specified by model_id. **comp_model_value[c][i][1]** shall be greater than or equal to 0 and less than 16.

When not present in the film grain characteristics SEI message, **comp_model_value[c][i][1]** shall be inferred as follows.

- If model_id is equal to 0, **comp_model_value[c][i][1]** shall be inferred to be equal to 8.
- Otherwise (model_id is equal to 1), **comp_model_value[c][i][1]** shall be inferred to be equal to 0.

comp_model_value[c][i][1] is interpreted as follows.

- If model_id is equal to 0, **comp_model_value[c][i][1]** indicates the horizontal high cut frequency to be used to filter the DCT of a block of 16x16 random values.
- Otherwise (model_id is equal to 1), **comp_model_value[c][i][1]** indicates the first order spatial correlation for neighbouring samples $(x-1, y)$ and $(x, y-1)$.

comp_model_value[c][i][2] provides the third model value for the model as specified by model_id. **comp_model_value[c][i][2]** shall be greater than or equal to 0 and less than 16.

When not present in the film grain characteristics SEI message, **comp_model_value[c][i][2]** shall be inferred as follows.

- If model_id is equal to 0, **comp_model_value[c][i][2]** shall be inferred to be equal to **comp_model_value[c][i][1]**
- Otherwise (model_id is equal to 1), **comp_model_value[c][i][2]** shall be inferred to be equal to 0.

comp_model_value[c][i][2] is interpreted as follows.

- If model_id is equal to 0, **comp_model_value[c][i][2]** indicates the vertical high cut frequency to be used to filter the DCT of a block of 16x16 random values.
- Otherwise (model_id is equal to 1), **comp_model_value[c][i][2]** indicates the colour correlation between consecutive colour components.

comp_model_value[c][i][3] provides the fourth model value for the model as specified by model_id. **comp_model_value[c][i][3]** shall be greater than or equal to 0 and less than or equal to **comp_model_value[c][i][1]**.

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

`comp_model_value[c][i][3]` is interpreted as follows.

- If `model_id` is equal to 0, `comp_model_value[c][i][3]` indicates the horizontal low cut frequency to be used to filter the DCT of a block of 16x16 random values.
- Otherwise (`model_id` is equal to 1), `comp_model_value[c][i][3]` indicates the first order spatial correlation for neighbouring samples (x-1, y-1) and (x+1, y-1).

`comp_model_value[c][i][4]` provides the fifth model value for the model as specified by `model_id`. `comp_model_value[c][i][4]` shall be greater than or equal to 0 and less than or equal to `comp_model_value[c][i][2]`.

When not present in the film grain characteristics SEI message, `comp_model_value[c][i][4]` shall be inferred to be equal to `model_id`.

`comp_model_value[c][i][4]` is interpreted as follows.

- If `model_id` is equal to 0, `comp_model_value[c][i][4]` indicates the vertical low cut frequency to be used to filter the DCT of a block of 16x16 random values.
- Otherwise (`model_id` is equal to 1), `comp_model_value[c][i][4]` indicates the aspect ratio of the modelled grain.

`comp_model_value[c][i][5]` provides the sixth model value for the model as specified by `model_id`. When not present in the film grain characteristics SEI message, `comp_model_value[c][i][5]` shall be inferred to be equal to 0.

`comp_model_value[c][i][5]` is interpreted as follows.

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

film_grain_characteristics_repetition_period specifies the persistence of the film grain characteristics SEI message and may specify a picture order count interval within which another film grain characteristics SEI message or the end of the coded video sequence shall be present in the bitstream. The value of `film_grain_characteristics_repetition_period` shall be in the range 0 to 16 384, inclusive.

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

`film_grain_characteristics_repetition_period` equal to 1 specifies that the film grain characteristics SEI message persists in output order until any of the following conditions are true.

- A new coded video sequence begins, or
- A picture in an access unit containing a film grain characteristics SEI message that is output having `PicOrderCnt()` greater than `PicOrderCnt(CurrPic)`.

`film_grain_characteristics_repetition_period` greater than 1 specifies that the film grain characteristics SEI message persists until any of the following conditions are true.

- A new coded video sequence begins, or
- A picture in an access unit containing a film grain characteristics SEI message is output having `PicOrderCnt()` greater than `PicOrderCnt(CurrPic)` and less than or equal to `PicOrderCnt(CurrPic) + film_grain_characteristics_repetition_period`.

`film_grain_characteristics_repetition_period` greater than 1 indicates that another film grain characteristics SEI message shall be present for a picture in an access unit that is output having `PicOrderCnt()` greater than `PicOrderCnt(CurrPic)` and less than or equal to `PicOrderCnt(CurrPic) + film_grain_characteristics_repetition_period`; unless the bitstream ends or a new coded video sequence begins without output of such a picture.

D.2.21 Deblocking filter display preference SEI message semantics

This SEI message provides the decoder with an indication of whether the display of the cropped result of the deblocking filter process specified in subclause 8.7 or of the cropped result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 is preferred by the encoder for the display of each decoded picture that is output.

NOTE 1 – The display process is not specified in this Recommendation | International Standard. The means by which an encoder determines what to indicate as its preference expressed in a deblocking filter display preference SEI message is also not specified in this Recommendation | International Standard, and the expression of an expressed preference in a deblocking filter display preference SEI message does not impose any requirement on the display process.

deblocking_display_preference_cancel_flag equal to 1 indicates that the SEI message cancels the persistence of any previous deblocking filter display preference SEI message in output order. **deblocking_display_preference_cancel_flag** equal to 0 indicates that a **display_prior_to_deblocking_preferred_flag** and **deblocking_display_preference_repetition_period** follow.

NOTE 2 – In the absence of the deblocking filter display preference SEI message, or after the receipt of a deblocking filter display preference SEI message in which **deblocking_display_preference_cancel_flag** is equal to 1, the decoder should infer that the display of the cropped result of the deblocking filter process specified in subclause 8.7 is preferred over the display of the cropped result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 for the display of each decoded picture that is output.

display_prior_to_deblocking_preferred_flag equal to 1 indicates that the encoder preference is for the display process (which is not specified in this Recommendation | International Standard) to display the cropped result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 rather than the cropped result of the deblocking filter process specified in subclause 8.7 for each picture that is cropped and output as specified in Annex C. **display_prior_to_deblocking_preferred_flag** equal to 0 indicates that the encoder preference is for the display process (which is not specified in this Recommendation | International Standard) to display the cropped result of the deblocking filter process specified in subclause 8.7 rather than the cropped result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 for each picture that is cropped and output as specified in Annex C.

NOTE 3 – The presence or absence of the deblocking filter display preference SEI message and the value of **display_prior_to_deblocking_preferred_flag** does not affect the requirements of the decoding process specified in this Recommendation | International Standard. Rather, it only provides an indication of when, in addition to fulfilling the requirements of this Recommendation | International Standard for the decoding process, enhanced visual quality might be obtained by performing the display process (which is not specified in this Recommendation | International Standard) in an alternative fashion. Encoders that use the deblocking filter display preference SEI message should be designed with an awareness that unless the encoder restricts its use of the DPB capacity specified in Annex A for the profile and level in use, some decoders may not have sufficient memory capacity for the storage of the result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 in addition to the storage of the result of the deblocking filter process specified in subclause 8.7 when reordering and delaying pictures for display, and such decoders would therefore not be able to benefit from the preference indication. By restricting its use of the DPB capacity, an encoder can be able to use at least half of the DPB capacity specified in Annex A while allowing the decoder to use the remaining capacity for storage of unfiltered pictures that have been indicated as preferable for display until the output time arrives for those pictures.

dec_frame_buffering_constraint_flag equal to 1 indicates that the use of the frame buffering capacity of the HRD decoded picture buffer (DPB) as specified by **max_dec_frame_buffering** has been constrained such that the coded video sequence will not require a decoded picture buffer with more than $\text{Max}(1, \text{max_dec_frame_buffering})$ frame buffers to enable the output of the decoded filtered or unfiltered pictures, as indicated by the deblocking filter display preference SEI messages, at the output times specified by the **dpb_output_delay** of the picture timing SEI messages.

dec_frame_buffering_constraint_flag equal to 0 indicates that the use of the frame buffering capacity in the HRD may or may not be constrained in the manner that would be indicated by **dec_frame_buffering_constraint_flag** equal to 1.

For purposes of determining the constraint imposed when **dec_frame_buffering_constraint_flag** is equal to 1, the quantity of frame buffering capacity used at any given point in time by each frame buffer of the DPB that contains a picture shall be derived as follows:

- If both of the following criteria are satisfied for the frame buffer, the frame buffer is considered to use two frame buffers of capacity for its storage.
 - The frame buffer contains a frame or one or more fields that is marked as "used for reference", and
 - The frame buffer contains a picture for which both of the following criteria are fulfilled.
 - The HRD output time of the picture is greater than the given point in time, and
 - It has been indicated in a deblocking filter display preference SEI message that the encoder preference for the picture is for the display process to display the cropped result of the picture construction process prior to the deblocking filter process specified in subclause 8.5.12 rather than the cropped result of the deblocking filter process specified in subclause 8.7, and
- Otherwise, the frame buffer is considered to use one frame buffer of DPB capacity for its storage.

When **dec_frame_buffering_constraint_flag** is equal to 1, the frame buffering capacity used by all of the frame buffers in the DPB that contain pictures, as derived in this manner, shall not be greater than $\text{Max}(1, \text{max_dec_frame_buffering})$ during the operation of the HRD for the coded video sequence.

The value of **dec_frame_buffering_constraint_flag** shall be the same in all deblocking filter display preference SEI messages of the coded video sequence.

deblocking_display_preference_repetition_period specifies the persistence of the film grain characteristics SEI message and may specify a picture order count interval within which another film grain characteristics SEI message or the end of the coded video sequence shall be present in the bitstream. The value of **deblocking_display_preference_repetition_period** shall be in the range 0 to 16 384, inclusive.

deblocking_display_preference_repetition_period equal to 0 specifies that the deblocking filter display preference SEI message applies to the current decoded picture only.

deblocking_display_preference_repetition_period equal to 1 specifies that the deblocking filter display preference SEI message persists in output order until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a deblocking filter display preference SEI message that is output having $\text{PicOrderCnt}()$ greater than $\text{PicOrderCnt}(\text{CurrPic})$.

deblocking_display_preference_repetition_period greater than 1 specifies that the deblocking filter display preference SEI message persists until any of the following conditions are true.

- A new coded video sequence begins
- A picture in an access unit containing a deblocking filter display preference SEI message is output having $\text{PicOrderCnt}()$ greater than $\text{PicOrderCnt}(\text{CurrPic})$ and less than or equal to $\text{PicOrderCnt}(\text{CurrPic}) + \text{deblocking_display_preference_repetition_period}$.

deblocking_display_preference_repetition_period greater than 1 indicates that another deblocking filter display preference SEI message shall be present for a picture in an access unit that is output having $\text{PicOrderCnt}()$ greater than $\text{PicOrderCnt}(\text{CurrPic})$ and less than or equal to $\text{PicOrderCnt}(\text{CurrPic}) + \text{deblocking_display_preference_repetition_period}$; unless the bitstream ends or a new coded video sequence begins without output of such a picture.

D.2.22 Stereo video information SEI message semantics

This SEI message provides the decoder with an indication that the entire coded video sequence consists of pairs of pictures forming stereo-view content.

The stereo video information SEI message shall not be present in any access unit of a coded video sequence unless a stereo video information SEI message is present in the first access unit of the coded video sequence.

field_views_flag equal to 1 indicates that all pictures in the current coded video sequence are fields and all fields of a particular parity are considered a left view and all fields of the opposite parity are considered a right view for stereo-view content. **field_views_flag** equal to 0 indicates that all pictures in the current coded video sequence are frames and alternating frames in output order represent a view of a stereo view. The value of **field_views_flag** shall be the same in all stereo video information SEI messages within a coded video sequence.

When the stereo video information SEI message is present and **field_views_flag** is equal to 1, the left view and right view of a stereo video pair shall be coded as a complementary field pair, the display time of the first field of the field pair in output order should be delayed to coincide with the display time of the second field of the field pair in output order, and the spatial locations of the samples in each individual field should be interpreted for display purposes as representing complete pictures as shown in Figure 6-1 rather than as spatially-distinct fields within a frame as shown in Figure 6-2.

NOTE – The display process is not specified in this Recommendation | International Standard.

top_field_is_left_view_flag equal to 1 indicates that the top fields in the coded video sequence represent a left view and the bottom fields in the coded video sequence represent a right view. **top_field_is_left_view_flag** equal to 0 indicates that the bottom fields in the coded video sequence represent a left view and the top fields in the coded video sequence represent a right view. When present, the value of **top_field_is_left_view_flag** shall be the same in all stereo video information SEI messages within a coded video sequence.

current_frame_is_left_view_flag equal to 1 indicates that the current picture is the left view of a stereo-view pair. **current_frame_is_left_view_flag** equal to 0 indicates that the current picture is the right view of a stereo-view pair.

next_frame_is_second_view_flag equal to 1 indicates that the current picture and the next picture in output order form a stereo-view pair, and the display time of the current picture should be delayed to coincide with the display time of the next picture in output order. **next_frame_is_second_view_flag** equal to 0 indicates that the current picture and the previous picture in output order form a stereo-view pair, and the display time of the current picture should not be delayed for purposes of stereo-view pairing.

left_view_self_contained_flag equal to 1 indicates that no inter prediction operations within the decoding process for the left-view pictures of the coded video sequence refer to reference pictures that are right-view pictures. **left_view_self_contained_flag** equal to 0 indicates that some inter prediction operations within the decoding process for the left-view pictures of the coded video sequence may or may not refer to reference pictures that are right-view pictures. Within a coded video sequence, the value of **left_view_self_contained_flag** in all stereo video information SEI messages shall be the same.

right_view_self_contained_flag equal to 1 indicates that no inter prediction operations within the decoding process for the right-view pictures of the coded video sequence refer to reference pictures that are left-view pictures. **right_view_self_contained_flag** equal to 0 indicates that some inter prediction operations within the decoding process for the right-view pictures of the coded video sequence may or may not refer to reference pictures that are left-view pictures. Within a coded video sequence, the value of **right_view_self_contained_flag** in all stereo video information SEI messages shall be the same.

D.2.23 Reserved SEI message semantics

This message consists of data reserved for future backward-compatible use by ITU-T | ISO/IEC. Encoders conforming to this Recommendation | International Standard shall not send reserved SEI messages until and unless the use of such messages has been specified by ITU-T | ISO/IEC. Decoders conforming to this Recommendation | International Standard that encounter reserved SEI messages shall discard their content without effect on the decoding process, except as specified in future Recommendations | International Standards specified by ITU-T | ISO/IEC.

reserved_sei_message_payload_byte is a byte reserved for future use by ITU-T | ISO/IEC.

Annex E

Video usability information

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

This Annex specifies syntax and semantics of the VUI parameters of the sequence parameter sets.

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

In Annex E, specification for presence of VUI parameters is also satisfied when those parameters (or some subset of them) are conveyed to decoders (or to the HRD) by other means not specified by this Recommendation | International Standard. When present in the bitstream, VUI parameters shall follow the syntax and semantics specified in subclauses 7.3.2.1 and 7.4.2.1 and this annex. When the content of VUI parameters is conveyed for the application by some means other than presence within the bitstream, the representation of the content of the VUI parameters is not required to use the same syntax specified in this annex. For the purpose of counting bits, only the appropriate bits that are actually present in the bitstream are counted.

E.1 VUI syntax

E.1.1 VUI parameters syntax

	C	Descriptor
vui_parameters() {		
aspect_ratio_info_present_flag	0	u(1)
if(aspect_ratio_info_present_flag) {		
aspect_ratio_idc	0	u(8)
if(aspect_ratio_idc == Extended_SAR) {		
sar_width	0	u(16)
sar_height	0	u(16)
}		
}		
overscan_info_present_flag	0	u(1)
if(overscan_info_present_flag)		
overscan_appropriate_flag	0	u(1)
video_signal_type_present_flag	0	u(1)
if(video_signal_type_present_flag) {		
video_format	0	u(3)
video_full_range_flag	0	u(1)
colour_description_present_flag	0	u(1)
if(colour_description_present_flag) {		
colour_primaries	0	u(8)
transfer_characteristics	0	u(8)
matrix_coefficients	0	u(8)
}		
}		
chroma_loc_info_present_flag	0	u(1)
if(chroma_loc_info_present_flag) {		
chroma_sample_loc_type_top_field	0	ue(v)
chroma_sample_loc_type_bottom_field	0	ue(v)
}		
timing_info_present_flag	0	u(1)
if(timing_info_present_flag) {		
num_units_in_tick	0	u(32)
time_scale	0	u(32)
fixed_frame_rate_flag	0	u(1)
}		
nal_hrd_parameters_present_flag	0	u(1)
if(nal_hrd_parameters_present_flag)		
hrd_parameters()		
vcl_hrd_parameters_present_flag	0	u(1)
if(vcl_hrd_parameters_present_flag)		
hrd_parameters()		
if(nal_hrd_parameters_present_flag vcl_hrd_parameters_present_flag)		
low_delay_hrd_flag	0	u(1)
pic_struct_present_flag	0	u(1)
bitstream_restriction_flag	0	u(1)
if(bitstream_restriction_flag) {		

motion_vectors_over_pic_boundaries_flag	0	u(1)
max_bytes_per_pic_denom	0	ue(v)
max_bits_per_mb_denom	0	ue(v)
log2_max_mv_length_horizontal	0	ue(v)
log2_max_mv_length_vertical	0	ue(v)
num_reorder_frames	0	ue(v)
max_dec_frame_buffering	0	ue(v)
}		
}		

E.1.2 HRD parameters syntax

hrd_parameters() {	C	Descriptor
cpb_cnt_minus1	0	ue(v)
bit_rate_scale	0	u(4)
cpb_size_scale	0	u(4)
for(SchedSelIdx = 0; SchedSelIdx <= cpb_cnt_minus1; SchedSelIdx++) {		
bit_rate_value_minus1 [SchedSelIdx]	0	ue(v)
cpb_size_value_minus1 [SchedSelIdx]	0	ue(v)
cbr_flag [SchedSelIdx]	0	u(1)
}		
initial_cpb_removal_delay_length_minus1	0	u(5)
cpb_removal_delay_length_minus1	0	u(5)
dpb_output_delay_length_minus1	0	u(5)
time_offset_length	0	u(5)
}		

E.2 VUI semantics

E.2.1 VUI parameters semantics

aspect_ratio_info_present_flag equal to 1 specifies that **aspect_ratio_idc** is present. **aspect_ratio_info_present_flag** equal to 0 specifies that **aspect_ratio_idc** is not present.

aspect_ratio_idc specifies the value of the sample aspect ratio of the luma samples. Table E-1 shows the meaning of the code. When **aspect_ratio_idc** indicates **Extended_SAR**, the sample aspect ratio is represented by **sar_width** and **sar_height**. When the **aspect_ratio_idc** syntax element is not present, **aspect_ratio_idc** value shall be inferred to be equal to 0.

Table E-1 – Meaning of sample aspect ratio indicator

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

sar_width indicates the horizontal size of the sample aspect ratio (in arbitrary units).

sar_height indicates the vertical size of the sample aspect ratio (in the same arbitrary units as sar_width).

sar_width and sar_height shall be relatively prime or equal to 0. When aspect_ratio_idc is equal to 0 or sar_width is equal to 0 or sar_height is equal to 0, the sample aspect ratio shall be considered unspecified by this Recommendation | International Standard.

overscan_info_present_flag equal to 1 specifies that the overscan_appropriate_flag is present. When overscan_info_present_flag is equal to 0 or is not present, the preferred display method for the video signal is unspecified.

overscan_appropriate_flag equal to 1 indicates that the cropped decoded pictures output are suitable for display using overscan. overscan_appropriate_flag equal to 0 indicates that the cropped decoded pictures output contain visually important information in the entire region out to the edges of the cropping rectangle of the picture, such that the cropped decoded pictures output should not be displayed using overscan. Instead, they should be displayed using either an exact match between the display area and the cropping rectangle, or using underscan.

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

video_signal_type_present_flag equal to 1 specifies that video_format, video_full_range_flag and colour_description_present_flag are present. video_signal_type_present_flag equal to 0, specify that video_format, video_full_range_flag and colour_description_present_flag are not present.

video_format indicates the representation of the pictures as specified in Table E-2, before being coded in accordance with this Recommendation | International Standard. When the video_format syntax element is not present, video_format value shall be inferred to be equal to 5.

Table E-2 – Meaning of video_format

video_format	Meaning
0	Component
1	PAL
2	NTSC
3	SECAM
4	MAC
5	Unspecified video format
6	Reserved
7	Reserved

video_full_range_flag indicates the black level and range of the luma and chroma signals as derived from E'_Y , E'_{PB} , and E'_{PR} or E'_R , E'_G , and E'_B analogue component signals.

When the video_full_range_flag syntax element is not present, the value of video_full_range_flag shall be inferred to be equal to 0.

colour_description_present_flag equal to 1 specifies that colour primaries, transfer characteristics and matrix coefficients are present. colour_description_present_flag equal to 0 specifies that colour primaries, transfer characteristics and matrix coefficients are not present.

colour_primaries indicates the chromaticity coordinates of the source primaries as specified in Table E-3 in terms of the CIE 1931 definition of x and y as specified by ISO/CIE 10527.

When the colour_primaries syntax element is not present, the value of colour_primaries shall be inferred to be equal to 2 (the chromaticity is unspecified or is determined by the application).

Table E-3 – Colour primaries

Value	Primaries	Informative Remark															
0	Reserved	For future use by ITU-T / ISO/IEC															
1	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.300</td> <td>0.600</td> </tr> <tr> <td>blue</td> <td>0.150</td> <td>0.060</td> </tr> <tr> <td>red</td> <td>0.640</td> <td>0.330</td> </tr> <tr> <td>white D65</td> <td>0.3127</td> <td>0.3290</td> </tr> </table>	primary	x	y	green	0.300	0.600	blue	0.150	0.060	red	0.640	0.330	white D65	0.3127	0.3290	ITU-R Recommendation BT.709-5
primary	x	y															
green	0.300	0.600															
blue	0.150	0.060															
red	0.640	0.330															
white D65	0.3127	0.3290															
2	Unspecified	Image characteristics are unknown or are determined by the application.															
3	Reserved																
4	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.21</td> <td>0.71</td> </tr> <tr> <td>blue</td> <td>0.14</td> <td>0.08</td> </tr> <tr> <td>red</td> <td>0.67</td> <td>0.33</td> </tr> <tr> <td>white C</td> <td>0.310</td> <td>0.316</td> </tr> </table>	primary	x	y	green	0.21	0.71	blue	0.14	0.08	red	0.67	0.33	white C	0.310	0.316	ITU-R Recommendation BT.470-6 System M
primary	x	y															
green	0.21	0.71															
blue	0.14	0.08															
red	0.67	0.33															
white C	0.310	0.316															
5	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.29</td> <td>0.60</td> </tr> <tr> <td>blue</td> <td>0.15</td> <td>0.06</td> </tr> <tr> <td>red</td> <td>0.64</td> <td>0.33</td> </tr> <tr> <td>white D65</td> <td>0.3127</td> <td>0.3290</td> </tr> </table>	primary	x	y	green	0.29	0.60	blue	0.15	0.06	red	0.64	0.33	white D65	0.3127	0.3290	ITU-R Recommendation BT.470-6 System B, G
primary	x	y															
green	0.29	0.60															
blue	0.15	0.06															
red	0.64	0.33															
white D65	0.3127	0.3290															
6	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.310</td> <td>0.595</td> </tr> <tr> <td>blue</td> <td>0.155</td> <td>0.070</td> </tr> <tr> <td>red</td> <td>0.630</td> <td>0.340</td> </tr> <tr> <td>white D65</td> <td>0.3127</td> <td>0.3290</td> </tr> </table>	primary	x	y	green	0.310	0.595	blue	0.155	0.070	red	0.630	0.340	white D65	0.3127	0.3290	Society of Motion Picture and Television Engineers 170M (1999)
primary	x	y															
green	0.310	0.595															
blue	0.155	0.070															
red	0.630	0.340															
white D65	0.3127	0.3290															
7	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.310</td> <td>0.595</td> </tr> <tr> <td>blue</td> <td>0.155</td> <td>0.070</td> </tr> <tr> <td>red</td> <td>0.630</td> <td>0.340</td> </tr> <tr> <td>white D65</td> <td>0.3127</td> <td>0.3290</td> </tr> </table>	primary	x	y	green	0.310	0.595	blue	0.155	0.070	red	0.630	0.340	white D65	0.3127	0.3290	Society of Motion Picture and Television Engineers 240M (1999)
primary	x	y															
green	0.310	0.595															
blue	0.155	0.070															
red	0.630	0.340															
white D65	0.3127	0.3290															
8	<table border="0"> <tr> <td>primary</td> <td>x</td> <td>y</td> </tr> <tr> <td>green</td> <td>0.243</td> <td>0.692 (Wratten 58)</td> </tr> <tr> <td>blue</td> <td>0.145</td> <td>0.049 (Wratten 47)</td> </tr> <tr> <td>red</td> <td>0.681</td> <td>0.319 (Wratten 25)</td> </tr> <tr> <td>white C</td> <td>0.310</td> <td>0.316</td> </tr> </table>	primary	x	y	green	0.243	0.692 (Wratten 58)	blue	0.145	0.049 (Wratten 47)	red	0.681	0.319 (Wratten 25)	white C	0.310	0.316	Generic film (colour filters using Illuminant C)
primary	x	y															
green	0.243	0.692 (Wratten 58)															
blue	0.145	0.049 (Wratten 47)															
red	0.681	0.319 (Wratten 25)															
white C	0.310	0.316															
9-255	Reserved	For future use by ITU-T / ISO/IEC															

transfer_characteristics indicates the opto-electronic transfer characteristic of the source picture as specified in Table E-4 as a function of a linear optical intensity input L_c with an analogue range of 0 to 1.

When the transfer_characteristics syntax element is not present, the value of transfer_characteristics shall be inferred to be equal to 2 (the transfer characteristics are unspecified or are determined by the application).

Table E-4 – Transfer characteristics

Value	Transfer Characteristic	Informative Remark
0	Reserved	For future use by ITU-T / ISO/IEC
1	$V = 1.099 L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500 L_c$ for $0.018 > L_c \geq 0$	ITU-R Recommendation BT.709-5
2	Unspecified	Image characteristics are unknown or are determined by the application.
3	Reserved	For future use by ITU-T / ISO/IEC
4	Assumed display gamma 2.2	ITU-R Recommendation BT.470-6 System M
5	Assumed display gamma 2.8	ITU-R Recommendation BT.470-6 System B, G
6	$V = 1.099 L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500 L_c$ for $0.018 > L_c \geq 0$	Society of Motion Picture and Television Engineers 170M (1999)
7	$V = 1.1115 L_c^{0.45} - 0.1115$ for $1 \geq L_c \geq 0.0228$ $V = 4.0 L_c$ for $0.0228 > L_c \geq 0$	Society of Motion Picture and Television Engineers 240M (1999)
8	$V = L_c$ for $1 > L_c \geq 0$	Linear transfer characteristics
9	$V = 1.0 - \text{Log}_{10}(L_c) \div 2$ for $1 \geq L_c \geq 0.01$ $V = 0.0$ for $0.01 > L_c \geq 0$	Logarithmic transfer characteristic (100:1 range)
10	$V = 1.0 - \text{Log}_{10}(L_c) \div 2.5$ for $1 \geq L_c \geq 0.0031622777$ $V = 0.0$ for $0.0031622777 > L_c \geq 0$	Logarithmic transfer characteristic (316.22777:1 range)
11..255	Reserved	For future use by ITU-T / ISO/IEC

matrix_coefficients describes the matrix coefficients used in deriving luma and chroma signals from the green, blue, and red primaries, as specified in Table E-5.

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

- BitDepth_C is equal to BitDepth_Y
- chroma_format_idc is equal to 3 (4:4:4)

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

matrix_coefficients shall not be equal to 8 unless one or both of the following conditions are true

- BitDepth_C is equal to BitDepth_Y
- BitDepth_C is equal to BitDepth_Y + 1 and chroma_format_idc is equal to 3 (4:4:4)

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

When the matrix_coefficients syntax element is not present, the value of matrix_coefficients shall be inferred to be equal to 2.

The interpretation of matrix_coefficients is defined as follows.

- E'_R, E'_G, and E'_B are analogue with values in the range of 0 to 1.
- White is specified as having E'_R equal to 1, E'_G equal to 1, and E'_B equal to 1.
- Black is specified as having E'_R equal to 0, E'_G equal to 0, and E'_B equal to 0.
- If video_full_range_flag is equal to 0, the following equations apply.
 - If matrix_coefficients is equal to 1, 4, 5, 6, or 7, the following equations apply.

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

$$C_b = \text{Round}((1 \ll (\text{BitDepth}_C - 8)) * (224 * E'_{PB} + 128)) \quad (\text{E-2})$$

$$C_r = \text{Round}((1 \ll (\text{BitDepth}_C - 8)) * (224 * E'_{PR} + 128)) \quad (\text{E-3})$$

- Otherwise, if `matrix_coefficients` is equal to 0 or 8, the following equations apply.

$$R = (1 \ll (\text{BitDepth}_Y - 8)) * (219 * E'_R + 16) \quad (\text{E-4})$$

$$G = (1 \ll (\text{BitDepth}_Y - 8)) * (219 * E'_G + 16) \quad (\text{E-5})$$

$$B = (1 \ll (\text{BitDepth}_Y - 8)) * (219 * E'_B + 16) \quad (\text{E-6})$$

- Otherwise, if `matrix_coefficients` is equal to 2, the interpretation of the `matrix_coefficients` syntax element is unknown or is determined by the application.
- Otherwise (`matrix_coefficients` is not equal to 0, 1, 2, 4, 5, 6, 7, or 8), the interpretation of the `matrix_coefficients` syntax element is reserved for future definition by ITU-T | ISO/IEC.
- Otherwise (`video_full_range_flag` is equal to 1), the following equations apply.
 - If `matrix_coefficients` is equal to 1, 4, 5, 6, or 7, the following equations apply.

$$Y = \text{Round}(((1 \ll \text{BitDepth}_Y) - 1) * E'_Y) \quad (\text{E-7})$$

$$C_b = \text{Round}(((1 \ll \text{BitDepth}_C) - 1) * E'_{PB} + (1 \ll (\text{BitDepth}_C - 1))) \quad (\text{E-8})$$

$$C_r = \text{Round}(((1 \ll \text{BitDepth}_C) - 1) * E'_{PR} + (1 \ll (\text{BitDepth}_C - 1))) \quad (\text{E-9})$$

- Otherwise, if `matrix_coefficients` is equal to 0 or 8, the following equations apply.

$$R = ((1 \ll \text{BitDepth}_Y) - 1) * E'_R \quad (\text{E-10})$$

$$G = ((1 \ll \text{BitDepth}_Y) - 1) * E'_G \quad (\text{E-11})$$

$$B = ((1 \ll \text{BitDepth}_Y) - 1) * E'_B \quad (\text{E-12})$$

- Otherwise, if `matrix_coefficients` is equal to 2, the interpretation of the `matrix_coefficients` syntax element is unknown or is determined by the application.
- Otherwise (`matrix_coefficients` is not equal to 0, 1, 2, 4, 5, 6, 7, or 8), the interpretation of the `matrix_coefficients` syntax element is reserved for future definition by ITU-T | ISO/IEC.
- If `matrix_coefficients` is not equal to 0 or 8, the following equations apply.

$$E'_Y = K_R * E'_R + (1 - K_R - K_B) * E'_G + K_B * E'_B \quad (\text{E-13})$$

$$E'_{PB} = 0.5 * (E'_B - E'_Y) \div (1 - K_B) \quad (\text{E-14})$$

$$E'_{PR} = 0.5 * (E'_R - E'_Y) \div (1 - K_R) \quad (\text{E-15})$$

NOTE 2 – Then E'_Y is analogue with values in the range of 0 to 1, E'_{PB} and E'_{PR} are analogue with values in the range of -0.5 to 0.5, and white is equivalently given by $E'_Y = 1$, $E'_{PB} = 0$, $E'_{PR} = 0$.

- Otherwise, if matrix_coefficients is equal to 0, the following equations apply.

$$Y = \text{Round}(G) \quad (\text{E-16})$$

$$Cb = \text{Round}(B) \quad (\text{E-17})$$

$$Cr = \text{Round}(R) \quad (\text{E-18})$$

- Otherwise (matrix_coefficients is equal to 8), the following applies.
 - If BitDepth_C is equal to BitDepth_V, the following equations apply.

$$Y = \text{Round}(0.5 * G + 0.25 * (R + B)) \quad (\text{E-19})$$

$$Cb = \text{Round}(0.5 * G - 0.25 * (R + B)) \quad (\text{E-20})$$

$$Cr = \text{Round}(0.5 * (R - B)) \quad (\text{E-21})$$

NOTE 3 – For purposes of the YCgCo nomenclature used in Table E-5, Cb and Cr of Equations E-20 and E-21 may be referred to as Cg and Co, respectively. The inverse conversion for the above four equations should be computed as.

$$t = Y - Cb \quad (\text{E-22})$$

$$G = Y + Cb \quad (\text{E-23})$$

$$B = t - Cr \quad (\text{E-24})$$

$$R = t + Cr \quad (\text{E-25})$$

- Otherwise (BitDepth_C is not equal to BitDepth_V), the following equations apply.

$$Cr = \text{Round}(R) - \text{Round}(B) \quad (\text{E-26})$$

$$t = \text{Round}(B) + (Cr \gg 1) \quad (\text{E-27})$$

$$Cb = \text{Round}(G) - t \quad (\text{E-28})$$

$$Y = t + (Cb \gg 1) \quad (\text{E-29})$$

NOTE 4 – For purposes of the YCgCo nomenclature used in Table E-5, Cb and Cr of Equations E-28 and E-26 may be referred to as Cg and Co, respectively. The inverse conversion for the above four equations should be computed as.

$$t = Y - (Cb \gg 1) \quad (\text{E-30})$$

$$G = t + Cb \quad (\text{E-31})$$

$$B = t - (Cr \gg 1) \quad (\text{E-32})$$

$$R = B + Cr \quad (\text{E-33})$$

Table E-5 – Matrix coefficients

Value	Matrix	Informative remark
0	GBR	Typically referred to as RGB; see Equations E-16 to E-18
1	$K_R = 0.2126; K_B = 0.0722$	ITU-R Recommendation BT.709-5 and Society of Motion Picture and Television Engineers RP177 (1993)
2	Unspecified	Image characteristics are unknown or are determined by the application.
3	Reserved	For future use by ITU-T / ISO/IEC
4	$K_R = 0.30; K_B = 0.11$	United States Federal Communications Commission Title 47 Code of Federal Regulations (2003) 73.682 (a) (20)
5	$K_R = 0.299; K_B = 0.114$	ITU-R Recommendation BT.470-6 System B, G
6	$K_R = 0.299; K_B = 0.114$	Society of Motion Picture and Television Engineers 170M (1999)
7	$K_R = 0.212; K_B = 0.087$	Society of Motion Picture and Television Engineers 240M (1999)
8	YCbCo	See Equations E-19 to E-33
9-255	Reserved	For future use by ITU-T / ISO/IEC

chroma_loc_info_present_flag equal to 1 specifies that **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** are present. **chroma_loc_info_present_flag** equal to 0 specifies that **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** are not present.

chroma_sample_loc_type_top_field and **chroma_sample_loc_type_bottom_field** specify the location of chroma samples for the top field and the bottom field as shown in Figure E-1. The value of **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** shall be in the range of 0 to 5, inclusive. When the **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** are not present, the values of **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** shall be inferred to be equal to 0.

NOTE 5 – When coding progressive source material, **chroma_sample_loc_type_top_field** and **chroma_sample_loc_type_bottom_field** should have the same value.

For each picture n where n indicates the n -th picture (in output order) that is output and picture n is not the last picture in the bitstream (in output order) that is output, the value of $\Delta t_{fi,dpb}(n)$ is specified by

$$\Delta t_{fi,dpb}(n) = \Delta t_{o,dpb}(n) \div \text{DeltaTfiDivisor} \quad (\text{E-34})$$

where $\Delta t_{o,dpb}(n)$ is specified in Equation C-13 and DeltaTfiDivisor is specified by Table E-6 based on the value of pic_struct_present_flag, field_pic_flag, and pic_struct for the coded video sequence containing picture n . Entries marked "-" in Table E-6 indicate a lack of dependence of DeltaTfiDivisor on the corresponding syntax element.

When fixed_frame_rate_flag is equal to 1 for a coded video sequence containing picture n , the value computed for $\Delta t_{fi,dpb}(n)$ shall be equal to t_c as specified in Equation C-1 (using the value of t_c for the coded video sequence containing picture n) when either or both of the following conditions are true for the following picture n_n that is specified for use in Equation C-13.

- picture n_n is in the same coded video sequence as picture n .
- picture n_n is in a different coded video sequence and fixed_frame_rate_flag is equal to 1 in the coded video sequence containing picture n_n and the value of num_units_in_tick \div time_scale is the same for both coded video sequences.

Table E-6 – Divisor for computation of $\Delta t_{fi,dpb}(n)$

pic_struct_present_flag	field_pic_flag	pic_struct	DeltaTfiDivisor
0	1	-	1
1	-	1	1
1	-	2	1
0	0	-	2
1	-	0	2
1	-	3	2
1	-	4	2
1	-	5	3
1	-	6	3
1	-	7	4
1	-	8	6

nal_hrd_parameters_present_flag equal to 1 specifies that NAL HRD parameters (pertaining to Type II bitstream conformance) are present. nal_hrd_parameters_present_flag equal to 0 specifies that NAL HRD parameters are not present.

NOTE 6 – When nal_hrd_parameters_present_flag is equal to 0, the conformance of the bitstream cannot be verified without provision of the NAL HRD parameters, including the NAL sequence HRD parameter information and all buffering period and picture timing SEI messages, by some means not specified in this Recommendation | International Standard.

When nal_hrd_parameters_present_flag is equal to 1, NAL HRD parameters (subclauses E.1.2 and E.2.2) immediately follow the flag.

The variable NalHrdBpPresentFlag is derived as follows.

- If any of the following is true, the value of NalHrdBpPresentFlag shall be set equal to 1.
 - nal_hrd_parameters_present_flag is present in the bitstream and is equal to 1
 - the need for presence of buffering periods for NAL HRD operation to be present in the bitstream in buffering period SEI messages is determined by the application, by some means not specified in this Recommendation | International Standard.
- Otherwise, the value of NalHrdBpPresentFlag shall be set equal to 0.

vcl_hrd_parameters_present_flag equal to 1 specifies that VCL HRD parameters (pertaining to all bitstream conformance) are present. vcl_hrd_parameters_present_flag equal to 0 specifies that VCL HRD parameters are not present.

NOTE 7 – When vcl_hrd_parameters_present_flag is equal to 0, the conformance of the bitstream cannot be verified without provision of the VCL HRD parameters and all buffering period and picture timing SEI messages, by some means not specified in this Recommendation | International Standard.

When `vcl_hrd_parameters_present_flag` is equal to 1, VCL HRD parameters (subclauses E.1.2 and E.2.2) immediately follow the flag.

The variable `VclHrdBpPresentFlag` is derived as follows.

- If any of the following is true, the value of `VclHrdBpPresentFlag` shall be set equal to 1.
 - `vcl_hrd_parameters_present_flag` is present in the bitstream and is equal to 1
 - the need for presence of buffering periods for VCL HRD operation to be present in the bitstream in buffering period SEI messages is determined by the application, by some means not specified in this Recommendation | International Standard.
- Otherwise, the value of `VclHrdBpPresentFlag` shall be set equal to 0.

The variable `CpbDpbDelaysPresentFlag` is derived as follows.

- If any of the following is true, the value of `CpbDpbDelaysPresentFlag` shall be set equal to 1.
 - `nal_hrd_parameters_present_flag` is present in the bitstream and is equal to 1
 - `vcl_hrd_parameters_present_flag` is present in the bitstream and is equal to 1
 - the need for presence of CPB and DPB output delays to be present in the bitstream in picture timing SEI messages is determined by the application, by some means not specified in this Recommendation | International Standard.
- Otherwise, the value of `CpbDpbDelaysPresentFlag` shall be set equal to 0.

low_delay_hrd_flag specifies the HRD operational mode as specified in Annex C. When `fixed_frame_rate_flag` is equal to 1, `low_delay_hrd_flag` shall be equal to 0.

NOTE 8 – When `low_delay_hrd_flag` is equal to 1, "big pictures" that violate the nominal CPB removal times due to the number of bits used by an access unit are permitted. It is expected, but not required, that such "big pictures" occur only occasionally.

pic_struct_present_flag equal to 1 specifies that picture timing SEI messages (subclause D.2.2) are present that include the `pic_struct` syntax element. `pic_struct_present_flag` equal to 0 specifies that the `pic_struct` syntax element is not present in picture timing SEI messages. When `pic_struct_present_flag` is not present, its value shall be inferred to be equal to 0.

bitstream_restriction_flag equal to 1, specifies that the following coded video sequence bitstream restriction parameters are present. `bitstream_restriction_flag` equal to 0, specifies that the following coded video sequence bitstream restriction parameters are not present.

motion_vectors_over_pic_boundaries_flag equal to 0 indicates that no sample outside the picture boundaries and no sample at a fractional sample position whose value is derived using one or more samples outside the picture boundaries is used to inter predict any sample. `motion_vectors_over_pic_boundaries_flag` equal to 1 indicates that one or more samples outside picture boundaries may be used in inter prediction. When the `motion_vectors_over_pic_boundaries_flag` syntax element is not present, `motion_vectors_over_pic_boundaries_flag` value shall be inferred to be equal to 1.

max_bytes_per_pic_denom indicates a number of bytes not exceeded by the sum of the sizes of the VCL NAL units associated with any coded picture in the coded video sequence.

The number of bytes that represent a picture in the NAL unit stream is specified for this purpose as the total number of bytes of VCL NAL unit data (i.e., the total of the `NumBytesInNALunit` variables for the VCL NAL units) for the picture. The value of `max_bytes_per_pic_denom` shall be in the range of 0 to 16, inclusive.

Depending on `max_bytes_per_pic_denom` the following applies.

- If `max_bytes_per_pic_denom` is equal to 0, no limits are indicated.
- Otherwise (`max_bytes_per_pic_denom` is not equal to 0), no coded picture shall be represented in the coded video sequence by more than the following number of bytes.

$$(\text{PicSizeInMbs} * \text{RawMbBits}) \div (8 * \text{max_bytes_per_pic_denom}) \quad (\text{E-35})$$

When the `max_bytes_per_pic_denom` syntax element is not present, the value of `max_bytes_per_pic_denom` shall be inferred to be equal to 2.

max_bits_per_mb_denom indicates the maximum number of coded bits of `macroblock_layer()` data for any macroblock in any picture of the coded video sequence. The value of `max_bits_per_mb_denom` shall be in the range of 0 to 16, inclusive.

Depending on `max_bits_per_mb_denom` the following applies.

- If `max_bits_per_mb_denom` is equal to 0, no limit is specified.
- Otherwise (`max_bits_per_mb_denom` is not equal to 0), no coded `macroblock_layer()` shall be represented in the bitstream by more than the following number of bits.

$$(128 + \text{RawMbBits}) \div \text{max_bits_per_mb_denom} \quad (\text{E-36})$$

Depending on `entropy_coding_mode_flag`, the bits of `macroblock_layer()` data are counted as follows.

- If `entropy_coding_mode_flag` is equal to 0, the number of bits of `macroblock_layer()` data is given by the number of bits in the `macroblock_layer()` syntax structure for a macroblock.
- Otherwise (`entropy_coding_mode_flag` is equal to 1), the number of bits of `macroblock_layer()` data for a macroblock is given by the number of times `read_bits(1)` is called in subclauses 9.3.3.2.2 and 9.3.3.2.3 when parsing the `macroblock_layer()` associated with the macroblock.

When the `max_bits_per_mb_denom` is not present, the value of `max_bits_per_mb_denom` shall be inferred to be equal to 1.

log2_max_mv_length_horizontal and **log2_max_mv_length_vertical** indicate the maximum absolute value of a decoded horizontal and vertical motion vector component, respectively, in $\frac{1}{4}$ luma sample units, for all pictures in the coded video sequence. A value of n asserts that no value of a motion vector component shall exceed the range from -2^n to $2^n - 1$, inclusive, in units of $\frac{1}{4}$ luma sample displacement. The value of `log2_max_mv_length_horizontal` shall be in the range of 0 to 16, inclusive. The value of `log2_max_mv_length_vertical` shall be in the range of 0 to 16, inclusive. When `log2_max_mv_length_horizontal` is not present, the values of `log2_max_mv_length_horizontal` and `log2_max_mv_length_vertical` shall be inferred to be equal to 16.

NOTE 9 – The maximum absolute value of a decoded vertical or horizontal motion vector component is also constrained by profile and level limits as specified in Annex A.

num_reorder_frames indicates the maximum number of frames, complementary field pairs, or non-paired fields that precede any frame, complementary field pair, or non-paired field in the coded video sequence in decoding order and follow it in output order. The value of `num_reorder_frames` shall be in the range of 0 to `max_dec_frame_buffering`, inclusive. When the `num_reorder_frames` syntax element is not present, the value of `num_reorder_frames` value shall be inferred to be equal to `max_dec_frame_buffering`.

max_dec_frame_buffering specifies the required size of the HRD decoded picture buffer (DPB) in units of frame buffers. The coded video sequence shall not require a decoded picture buffer with size of more than $\text{Max}(1, \text{max_dec_frame_buffering})$ frame buffers to enable the output of decoded pictures at the output times specified by `dpb_output_delay` of the picture timing SEI messages. The value of `max_dec_frame_buffering` shall be in the range of `num_ref_frames` to `MaxDpbSize` (as specified in subclause A.3.1 or A.3.2), inclusive. When the `max_dec_frame_buffering` syntax element is not present, the value of `max_dec_frame_buffering` shall be inferred to be equal to `MaxDpbSize`.

E.2.2 HRD parameters semantics

cpb_cnt_minus1 plus 1 specifies the number of alternative CPB specifications in the bitstream. The value of `cpb_cnt_minus1` shall be in the range of 0 to 31, inclusive. When `low_delay_hrd_flag` is equal to 1, `cpb_cnt_minus1` shall be equal to 0. When `cpb_cnt_minus1` is not present, it shall be inferred to be equal to 0.

bit_rate_scale (together with `bit_rate_value_minus1[SchedSelIdx]`) specifies the maximum input bit rate of the `SchedSelIdx`-th CPB.

cpb_size_scale (together with `cpb_size_value_minus1[SchedSelIdx]`) specifies the CPB size of the `SchedSelIdx`-th CPB.

bit_rate_value_minus1[SchedSelIdx] (together with `bit_rate_scale`) specifies the maximum input bit rate for the `SchedSelIdx`-th CPB. `bit_rate_value_minus1[SchedSelIdx]` shall be in the range of 0 to $2^{32} - 2$, inclusive. For any `SchedSelIdx > 0`, `bit_rate_value_minus1[SchedSelIdx]` shall be greater than `bit_rate_value_minus1[SchedSelIdx - 1]`. The bit rate in bits per second is given by

$$\text{BitRate[SchedSelIdx]} = (\text{bit_rate_value_minus1[SchedSelIdx]} + 1) * 2^{(6 + \text{bit_rate_scale})} \quad (\text{E-37})$$

When the `bit_rate_value_minus1[SchedSelIdx]` syntax element is not present, the value of `BitRate[SchedSelIdx]` shall be inferred as follows.

- If `profile_idc` is equal to 66, 77, or 88, `BitRate[SchedSelIdx]` shall be inferred to be equal to $1000 * \text{MaxBR}$ for VCL HRD parameters and to be equal to $1200 * \text{MaxBR}$ for NAL HRD parameters, where `MaxBR` is specified in subclause A.3.1.
- Otherwise, `BitRate[SchedSelIdx]` shall be inferred to be equal to `cpbBrVclFactor * MaxBR` for VCL HRD parameters and to be equal to `cpbBrNalFactor * MaxBR` for NAL HRD parameters, where `cpbBrVclFactor`, `cpbBrNalFactor`, and `MaxBR` are specified in subclause A.3.3.

`cpb_size_value_minus1[SchedSelIdx]` is used together with `cpb_size_scale` to specify the `SchedSelIdx`-th CPB size. `cpb_size_value_minus1[SchedSelIdx]` shall be in the range of 0 to $2^{32} - 2$, inclusive. For any `SchedSelIdx` greater than 0, `cpb_size_value_minus1[SchedSelIdx]` shall be less than or equal to `cpb_size_value_minus1[SchedSelIdx - 1]`.

The CPB size in bits is given by

$$\text{CpbSize[SchedSelIdx]} = (\text{cpb_size_value_minus1[SchedSelIdx]} + 1) * 2^{(4 + \text{cpb_size_scale})} \quad (\text{E-38})$$

When the `cpb_size_value_minus1[SchedSelIdx]` syntax element is not present, the value of `CpbSize[SchedSelIdx]` shall be inferred as follows.

- If `profile_idc` is equal to 66, 77, or 88, `CpbSize[SchedSelIdx]` shall be inferred to be equal to $1000 * \text{MaxCPB}$ for VCL HRD parameters and to be equal to $1200 * \text{MaxCPB}$ for NAL HRD parameters, where `MaxCPB` is specified in subclause A.3.1.
- Otherwise, `CpbSize[SchedSelIdx]` shall be inferred to be equal to `cpbBrVclFactor * MaxCPB` for VCL HRD parameters and to be equal to `cpbBrNalFactor * MaxCPB` for NAL HRD parameters, where `cpbBrVclFactor`, `cpbBrNalFactor`, and `MaxCPB` are specified in subclause A.3.3.

`cbr_flag[SchedSelIdx]` equal to 0 specifies that to decode this bitstream by the HRD using the `SchedSelIdx`-th CPB specification, the hypothetical stream delivery scheduler (HSS) operates in an intermittent bit rate mode. `cbr_flag[SchedSelIdx]` equal to 1 specifies that the HSS operates in a constant bit rate (CBR) mode. When the `cbr_flag[SchedSelIdx]` syntax element is not present, the value of `cbr_flag` shall be inferred to be equal to 0.

`initial_cpb_removal_delay_length_minus1` specifies the length in bits of the `initial_cpb_removal_delay[SchedSelIdx]` and `initial_cpb_removal_delay_offset[SchedSelIdx]` syntax elements of the buffering period SEI message. The length of `initial_cpb_removal_delay[SchedSelIdx]` and of `initial_cpb_removal_delay_offset[SchedSelIdx]` is `initial_cpb_removal_delay_length_minus1 + 1`. When the `initial_cpb_removal_delay_length_minus1` syntax element is present in more than one `hrd_parameters()` syntax structure within the VUI parameters syntax structure, the value of the `initial_cpb_removal_delay_length_minus1` parameters shall be equal in both `hrd_parameters()` syntax structures. When the `initial_cpb_removal_delay_length_minus1` syntax element is not present, it shall be inferred to be equal to 23.

`cpb_removal_delay_length_minus1` specifies the length in bits of the `cpb_removal_delay` syntax element. The length of the `cpb_removal_delay` syntax element of the picture timing SEI message is `cpb_removal_delay_length_minus1 + 1`. When the `cpb_removal_delay_length_minus1` syntax element is present in more than one `hrd_parameters()` syntax structure within the VUI parameters syntax structure, the value of the `cpb_removal_delay_length_minus1` parameters shall be equal in both `hrd_parameters()` syntax structures. When the `cpb_removal_delay_length_minus1` syntax element is not present, it shall be inferred to be equal to 23.

`dpb_output_delay_length_minus1` specifies the length in bits of the `dpb_output_delay` syntax element. The length of the `dpb_output_delay` syntax element of the picture timing SEI message is `dpb_output_delay_length_minus1 + 1`. When the `dpb_output_delay_length_minus1` syntax element is present in more than one `hrd_parameters()` syntax structure within the VUI parameters syntax structure, the value of the `dpb_output_delay_length_minus1` parameters shall be equal in both `hrd_parameters()` syntax structures. When the `dpb_output_delay_length_minus1` syntax element is not present, it shall be inferred to be equal to 23.

`time_offset_length` greater than 0 specifies the length in bits of the `time_offset` syntax element. `time_offset_length` equal to 0 specifies that the `time_offset` syntax element is not present. When the `time_offset_length` syntax element is present in more than one `hrd_parameters()` syntax structure within the VUI parameters syntax structure, the value of the `time_offset_length` parameters shall be equal in both `hrd_parameters()` syntax structures. When the `time_offset_length` syntax element is not present, it shall be inferred to be equal to 24.

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Series H	Audiovisual and multimedia systems
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Series R	Telegraph transmission
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