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Information technology — Generic coding of moving pictures and associated audio information —

Part 2: **Video**

Technologies de l'information — Codage générique des images animées et du son associé —

Partie 2: Données vidéo

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

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Foreword

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

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

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

ISO/IEC 13818-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*, in collaboration with ITU-T. The identical text is published as ITU-T Rec. H.262 (2012).

This third edition cancels and replaces the second edition (ISO/IEC 13818-2:2000), which has been technically revised. It also incorporates the Amendments ISO/IEC 13818-2:2000/Amd.1:2001, ISO/IEC 13818-2:2000/Amd.2:2007 and ISO/IEC 13818-2:2000/Amd.3:2010, and the Technical Corrigenda ISO/IEC 13818-2:2000/Cor.1:2002 and ISO/IEC 13818-2:2000/Cor.2:2007.

ISO/IEC 13818 consists of the following parts, under the general title *Information technology — Generic coding of moving pictures and associated audio information*:

- *Part 1: Systems*
- *Part 2: Video*
- *Part 3: Audio*
- *Part 4: Conformance testing*
- *Part 5: Software simulation*
- *Part 6: Extensions for DSM-CC*
- *Part 7: Advanced Audio Coding (AAC)*
- *Part 9: Extension for real time interface for systems decoders*
- *Part 10: Conformance extensions for Digital Storage Media Command and Control (DSM-CC)*
- *Part 11: IPMP on MPEG-2 systems*

CONTENTS

Introduction

Intro. 1 Purpose

This Part of this Recommendation | International Standard was developed in response to the growing need for a generic coding method of moving pictures and of associated sound for various applications such as digital storage media, television broadcasting and communication. The use of this Specification means that motion video can be manipulated as a form of computer data and can be stored on various storage media, transmitted and received over existing and future networks and distributed on existing and future broadcasting channels.

Intro. 2 Application

The applications of this Specification cover, but are not limited to, such areas as listed below:

BSS	Broadcasting Satellite Service (to the home)
CATV	Cable TV Distribution on optical networks, copper, etc.
CDAD	Cable Digital Audio Distribution
DSB	Digital Sound Broadcasting (terrestrial and satellite broadcasting)
DTTB	Digital Terrestrial Television Broadcasting
EC	Electronic Cinema
ENG	Electronic News Gathering (including SNG, Satellite News Gathering)
FSS	Fixed Satellite Service (e.g. to head ends)
HTT	Home Television Theatre
IPC	Interpersonal Communications (videoconferencing, videophone, etc.)
ISM	Interactive Storage Media (optical disks, etc.)
MMM	Multimedia Mailing
NCA	News and Current Affairs
NDB	Networked Database Services (via ATM, etc.)
RVS	Remote Video Surveillance
SSM	Serial Storage Media (digital VTR, etc.)

Intro. 3 Profiles and levels

This Specification is intended 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 communications. In the course of creating this Specification, various requirements from typical applications have been considered, necessary algorithmic elements have been developed, and they have been integrated into a single syntax. Hence, this Specification will facilitate the bitstream 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 "profile" and "level". These and other related terms are formally defined in clause 3.

A "profile" is a defined subset of the entire bitstream syntax that is defined by this Specification. 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 parameters in the bitstream. For instance, it is possible to specify frame sizes as large as (approximately) 2^{14} samples wide by 2^{14} lines high. It is currently neither practical nor economic to implement a decoder capable of dealing with all possible frame sizes.

In order to deal with this problem, "levels" are defined within each profile. A level is a defined set of constraints imposed on parameters in the bitstream. These constraints may be simple limits on numbers. Alternatively they may take the form of constraints on arithmetic combinations of the parameters (e.g. frame width multiplied by frame height multiplied by frame rate).

Bitstreams complying with this Specification use a common syntax. In order to achieve a subset of the complete syntax, flags and parameters are included in the bitstream that signal the presence or otherwise of syntactic elements that occur later in the bitstream. In order to specify constraints on the syntax (and hence define a profile), it is thus only necessary to constrain the values of these flags and parameters that specify the presence of later syntactic elements.

Intro. 4 The scalable and the non-scalable syntax

The full syntax can be divided into two major categories: One is the non-scalable syntax, which is structured as a super set of the syntax defined in ISO/IEC 11172-2. The main feature of the non-scalable syntax is the extra compression tools for interlaced video signals. The second is the scalable syntax, the key property of which is to enable the reconstruction of useful video from pieces of a total bitstream. This is achieved by structuring the total bitstream in two or more layers, starting from a standalone base layer and adding a number of enhancement layers. The base layer can use the non-scalable syntax, or in some situations conform to the ISO/IEC 11172-2 syntax.

Intro. 4.1 Overview of the non-scalable syntax

The coded representation defined in the non-scalable syntax achieves a high compression ratio while preserving good image quality. The algorithm is not lossless as the exact sample values are not preserved during coding. Obtaining good image quality at the bit rates of interest demands very high compression, which is not achievable with intra picture coding alone. The need for random access, however, is best satisfied with pure intra picture coding. The choice of the techniques is based on the need to balance a high image quality and compression ratio with the requirement to make random access to the coded bitstream.

A number of techniques are used to achieve high compression. The algorithm first uses block-based motion compensation to reduce the temporal redundancy. Motion compensation is used both for causal prediction of the current picture from a previous picture, and for non-causal, interpolative prediction from past and future pictures. Motion vectors are defined for each 16-sample by 16-line region of the picture. The prediction error, is further compressed using the Discrete Cosine Transform (DCT) to remove spatial correlation before it is quantized in an irreversible process that discards the less important information. Finally, the motion vectors are combined with the quantized DCT information, and encoded using variable length codes.

Intro. 4.1.1 Temporal processing

Because of the conflicting requirements of random access and highly efficient compression, three main picture types are defined. Intra-coded pictures (I-pictures) are coded without reference to other pictures. They provide access points to the coded sequence where decoding can begin, but are coded with only moderate compression. Predictive coded pictures (P-pictures) are coded more efficiently using motion compensated prediction from a past intra or predictive coded picture and are generally used as a reference for further prediction. Bidirectionally-predictive coded pictures (B-pictures) provide the highest degree of compression but require both past and future reference pictures for motion compensation. Bidirectionally-predictive coded pictures are never used as references for prediction (except in the case that the resulting picture is used as a reference in a spatially scalable enhancement layer). The organization of the three picture types in a sequence is very flexible. The choice is left to the encoder and will depend on the requirements of the application. Figure Intro. 1 illustrates an example of the relationship among the three different picture types.

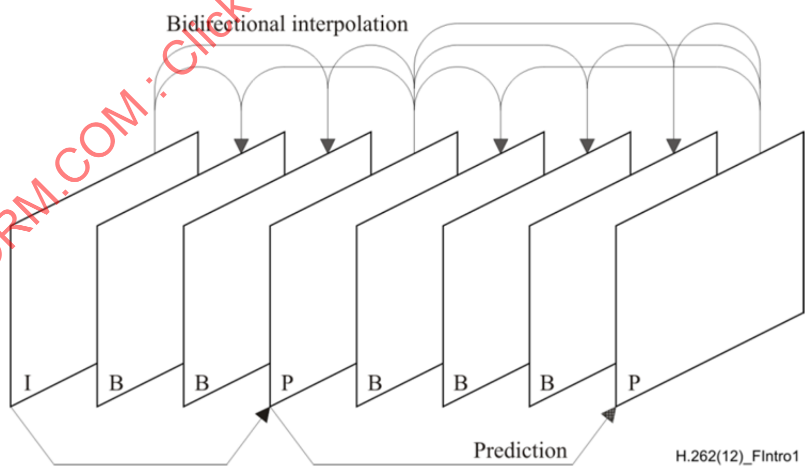


Figure Intro.1 – Example of temporal picture structure

Intro. 4.1.2 Coding interlaced video

Each frame of interlaced video consists of two fields which are separated by one field-period. The Specification allows either the frame to be encoded as picture or the two fields to be encoded as two pictures. Frame encoding or field encoding can be adaptively selected on a frame-by-frame basis. Frame encoding is typically preferred when the video scene contains significant detail with limited motion. Field encoding, in which the second field can be predicted from the first, works better when there is fast movement.

Intro. 4.1.3 Motion representation – Macroblocks

As in ISO/IEC 11172-2, the choice of 16 by 16 macroblocks for the motion-compensation unit is a result of the trade-off between the coding gain provided by using motion information and the overhead needed to represent it. Each macroblock can be temporally predicted in one of a number of different ways. For example, in frame encoding, the prediction from the previous reference frame can itself be either frame-based or field-based. Depending on the type of the macroblock, motion vector information and other side information is encoded with the compressed prediction error in each macroblock. The motion vectors are encoded differentially with respect to the last encoded motion vectors using variable length codes. The maximum length of the motion vectors that may be represented can be programmed, on a picture-by-picture basis, so that the most demanding applications can be met without compromising the performance of the system in more normal situations.

It is the responsibility of the encoder to calculate appropriate motion vectors. This Specification does not specify how this should be done.

Intro. 4.1.4 Spatial redundancy reduction

Both source pictures and prediction errors have high spatial redundancy. This Specification uses a block-based DCT method with visually weighted quantization and run-length coding. After motion compensated prediction or interpolation, the resulting prediction error is split into 8 by 8 blocks. These are transformed into the DCT domain where they are weighted before being quantized. After quantization many of the DCT coefficients are zero in value and so two-dimensional run-length and variable length coding is used to encode the remaining DCT coefficients efficiently.

Intro. 4.1.5 Chrominance formats

In addition to the 4:2:0 format supported in ISO/IEC 11172-2 this Specification supports 4:2:2 and 4:4:4 chrominance formats.

Intro. 4.2 Scalable extensions

The scalability tools in this Specification are designed to support applications beyond that supported by single layer video. Among the noteworthy applications areas addressed are video telecommunications, video on Asynchronous Transfer Mode (ATM) networks, interworking of video standards, video service hierarchies with multiple spatial, temporal and quality resolutions, HDTV with embedded TV, systems allowing migration to higher temporal resolution HDTV, etc. Although a simple solution to scalable video is the simulcast technique which is based on transmission/storage of multiple independently coded reproductions of video, a more efficient alternative is scalable video coding, in which the bandwidth allocated to a given reproduction of video can be partially re-utilized in coding of the next reproduction of video. In scalable video coding, it is assumed that given a coded bitstream, decoders of various complexities can decode and display appropriate reproductions of coded video. A scalable video encoder is likely to have increased complexity when compared to a single layer encoder. However, this Recommendation | International Standard provides several different forms of scalabilities that address non-overlapping applications with corresponding complexities. The basic scalability tools offered are:

- data partitioning;
- SNR scalability;
- spatial scalability; and
- temporal scalability.

Moreover, combinations of these basic scalability tools are also supported and are referred to as *hybrid scalability*. In the case of basic scalability, two layers of video referred to as the *lower layer* and the *enhancement layer* are allowed, whereas in hybrid scalability up to three layers are supported. Tables Intro. 1 to Intro. 3 provide a few example applications of various scalabilities.

Table Intro. 1 – Applications of SNR scalability

Lower layer	Enhancement layer	Application
Recommendation ITU-R BT.601	Same resolution and format as lower layer	Two quality service for Standard TV (SDTV)
High Definition	Same resolution and format as lower layer	Two quality service for HDTV
4:2:0 high definition	4:2:2 chroma simulcast	Video production / distribution

Table Intro. 2 – Applications of spatial scalability

Base	Enhancement	Application
Progressive (30 Hz)	Progressive (30 Hz)	Compatibility or scalability CIF/SCIF
Interlace (30 Hz)	Interlace (30 Hz)	HDTV/SDTV scalability
Progressive (30 Hz)	Interlace (30 Hz)	ISO/IEC 11172-2/compatibility with this Specification
Interlace (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV

Table Intro. 3 – Applications of temporal scalability

Base	Enhancement	Higher	Application
Progressive (30 Hz)	Progressive (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV
Interlace (30 Hz)	Interlace (30 Hz)	Progressive (60 Hz)	Migration to high resolution progressive HDTV

Intro. 4.2.1 Spatial scalable extension

Spatial scalability is a tool intended for use in video applications involving telecommunications, interworking of video standards, video database browsing, interworking of HDTV and TV, etc., i.e. video systems with the primary common feature that a minimum of two layers of spatial resolution are necessary. Spatial scalability involves generating two spatial resolution video layers from a single video source such that the lower layer is coded by itself to provide the basic spatial resolution and the enhancement layer employs the spatially interpolated lower layer and carries the full spatial resolution of the input video source. The lower and the enhancement layers may either both use the coding tools in this Specification, or the ISO/IEC 11172-2 Standard for the lower layer and this Specification for the enhancement layer. The latter case achieves a further advantage by facilitating interworking between video coding standards. Moreover, spatial scalability offers flexibility in choice of video formats to be employed in each layer. An additional advantage of spatial scalability is its ability to provide resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer data can be sent over a channel with poor error performance.

Intro. 4.2.2 SNR scalable extension

SNR scalability is a tool intended for use in video applications involving telecommunications, video services with multiple qualities, standard TV and HDTV, i.e. video systems with the primary common feature that a minimum of two layers of video quality are necessary. SNR scalability involves generating two video layers of same spatial resolution but different video qualities from a single video source such that the lower layer is coded by itself to provide the basic video quality and the enhancement layer is coded to enhance the lower layer. The enhancement layer when added back to the lower layer regenerates a higher quality reproduction of the input video. The lower and the enhancement layers may either use this Specification or ISO/IEC 11172-2 Standard for the lower layer and this Specification for the enhancement layer. An additional advantage of SNR scalability is its ability to provide high degree of resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer data can be sent over a channel with poor error performance.

Intro. 4.2.3 Temporal scalable extension

Temporal scalability is a tool intended for use in a range of diverse video applications from telecommunications to HDTV for which migration to higher temporal resolution systems from that of lower temporal resolution systems may be necessary. In many cases, the lower temporal resolution video systems may be either the existing systems or the less expensive early generation systems, with the motivation of introducing more sophisticated systems gradually. Temporal scalability involves partitioning of video frames into layers, whereas the lower layer is coded by itself to provide the basic temporal rate and the enhancement layer is coded with temporal prediction with respect to the lower layer, these layers when decoded and temporal multiplexed to yield full temporal resolution of the video source. The lower temporal resolution systems may only decode the lower layer to provide basic temporal resolution, whereas more sophisticated systems of the future may decode both layers and provide high temporal resolution video while maintaining interworking with earlier generation systems. An additional advantage of temporal scalability is its ability to provide resilience to transmission errors as the more important data of the lower layer can be sent over channel with better error performance, while the less critical enhancement layer can be sent over a channel with poor error performance.

Intro. 4.2.4 Data partitioning extension

Data partitioning is a tool intended for use when two channels are available for transmission and/or storage of a video bitstream, as may be the case in ATM networks, terrestrial broadcast, magnetic media, etc. The bitstream is partitioned between these channels such that more critical parts of the bitstream (such as headers, motion vectors, low frequency DCT coefficients) are transmitted in the channel with the better error performance, and less critical data (such as higher frequency DCT coefficients) is transmitted in the channel with poor error performance. Thus, degradation to channel errors are minimized since the critical parts of a bitstream are better protected. Data from neither channel may be decoded on a decoder that is not intended for decoding data partitioned bitstreams.

INTERNATIONAL STANDARD
ITU-T RECOMMENDATION

Information technology – Generic coding of moving pictures and associated audio information: Video

1 Scope

This Recommendation | International Standard specifies the coded representation of picture information for digital storage media and digital video communication and specifies the decoding process. The representation supports constant bit rate transmission, variable bit rate transmission, random access, channel hopping, scalable decoding, bitstream editing, as well as special functions such as fast forward playback, fast reverse playback, slow motion, pause and still pictures. This Recommendation | International Standard is forward compatible with ISO/IEC 11172-2 and upward or downward compatible with EDTV, HDTV, SDTV formats.

This Recommendation | International Standard is primarily applicable to digital storage media, video broadcast and communication. The storage media may be directly connected to the decoder, or via communications means such as busses, LANs, or telecommunications links.

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 indicated below. Members of IEC and ISO maintain registers of currently valid International Standards. The Telecommunication Standardization Bureau of ITU maintains a list of currently valid ITU-T Recommendations.

– IEC 60461 (1986), *Time and control code for video tape recorders.*

– ISO/IEC 11172-2:1993, *Information technology – Coding of moving pictures and associated audio for digital storage media at up to about 1,5 Mbit/s – Part 2: Video.*

– ISO/IEC 23002-1:2006, *Information technology – MPEG video technologies – Part 1: Accuracy requirements for implementation of integer-output 8x8 inverse discrete cosine transform.*

– Recommendation ITU-R BT.470-6 (1998), *Conventional television systems*.

– Recommendation ITU-R BT.601-7 (2011), *Studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios*.

– Recommendation ITU-T H.320 (2004), *Narrow-band visual telephone systems and terminal equipment.*

3 Definitions

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

3.1 **AC coefficient**: Any DCT coefficient for which the frequency in one or both dimensions is non-zero.

3.2 **big picture**: A coded picture that would cause VBV buffer underflow as defined in C.7. Big pictures can only occur in sequences where low_delay is equal to 1. "Skipped picture" is a term that is sometimes used to describe the same concept.

3.3 **B-field picture**: A field structure B-picture.

3.4 **B-frame picture**: A frame structure B-picture.

3.5 **B-picture**; **bidirectionally predictive-coded picture**: A picture that is coded using motion compensated prediction from past and/or future reference fields or frames.

3.6 **backward compatibility**: A newer coding standard is backward compatible with an older coding standard if decoders designed to operate with the older coding standard are able to continue to operate by decoding all or part of a bitstream produced according to the newer coding standard.

3.7 backward motion vector: A motion vector that is used for motion compensation from a reference frame or reference field at a later time in display order.

3.8 backward prediction: Prediction from the future reference frame (field).

3.9 base layer: First, independently decodable layer of a scalable hierarchy.

3.10 bitstream; stream: An ordered series of bits that forms the coded representation of the data.

3.11 bit rate: The rate at which the coded bitstream is delivered from the storage medium to the input of a decoder.

3.12 block: An 8-row by 8-column matrix of samples, or 64 DCT coefficients (source, quantized or de-quantized).

3.13 bottom field: One of two fields that comprise a frame. Each line of a bottom field is spatially located immediately below the corresponding line of the top field.

3.14 byte aligned: A bit in a coded bitstream is byte-aligned if its position is a multiple of 8 bits from the first bit in the stream.

3.15 byte: Sequence of 8 bits.

3.16 channel: A digital medium that stores or transports a bitstream constructed according to Rec. ITU-T H.262 | ISO/IEC 13818-2.

3.17 chrominance format: Defines the number of chrominance blocks in a macroblock.

3.18 chroma simulcast: A type of scalability (which is a subset of SNR scalability) where the enhancement layer(s) contain only coded refinement data for the DC coefficients, and all the data for the AC coefficients, of the chrominance components.

3.19 chrominance component: A matrix, block or single sample representing one of the two colour difference signals related to the primary colours in the manner defined in the bitstream. The symbols used for the chrominance signals are Cr and Cb.

3.20 coded B-frame: A B-frame picture or a pair of B-field pictures.

3.21 coded frame: A coded frame is a coded I-frame, a coded P-frame or a coded B-frame.

3.22 coded I-frame: An I-frame picture or a pair of field pictures, where the first field picture is an I-picture and the second field picture is an I-picture or a P-picture.

3.23 coded P-frame: A P-frame picture or a pair of P-field pictures.

3.24 coded picture: A coded picture is made of a picture header, the optional extensions immediately following it, and the following picture data. A coded picture may be a coded frame or a coded field.

3.25 coded video bitstream: A coded representation of a series of one or more pictures as defined in Rec. ITU-T H.262 | ISO/IEC 13818-2.

3.26 coded order: The order in which the pictures are transmitted and decoded. This order is not necessarily the same as the display order.

3.27 coded representation: A data element as represented in its encoded form.

3.28 coding parameters: The set of user-definable parameters that characterize a coded video bitstream. Bitstreams are characterized by coding parameters. Decoders are characterized by the bitstreams that they are capable of decoding.

3.29 component: A matrix, block or single sample from one of the three matrices (luminance and two chrominance) that make up a picture.

3.30 compression: Reduction in the number of bits used to represent an item of data.

3.31 constant bit rate coded video: A coded video bitstream with a constant bit rate.

3.32 constant bit rate: Operation where the bit rate is constant from start to finish of the coded bitstream.

3.33 data element: An item of data as represented before encoding and after decoding.

3.34 data partitioning: A method for dividing a bitstream into two separate bitstreams for error resilience purposes. The two bitstreams have to be recombined before decoding.

3.35 D-picture: A type of picture that shall not be used except in ISO/IEC 11172-2.

3.36 DC coefficient: The DCT coefficient for which the frequency is zero in both dimensions.

3.37 DCT coefficient: The amplitude of a specific cosine basis function.

3.38 **decoder input buffer**: The First-In First-Out (FIFO) buffer specified in the video buffering verifier.

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

3.40 **decoding (process)**: The process defined in Rec. ITU-T H.262 | ISO/IEC 13818-2 that reads an input coded bitstream and produces decoded pictures.

3.41 **dequantization**: The process of rescaling the quantized DCT coefficients after their representation in the bitstream has been decoded and before they are presented to the inverse DCT.

3.42 **digital storage media (DSM)**: A digital storage or transmission device or system.

3.43 **discrete cosine transform (DCT)**: Either the forward discrete cosine transform or the inverse discrete cosine transform. The DCT is an invertible, discrete orthogonal transformation. The inverse DCT is defined in Annex A of Rec. ITU-T H.262 | ISO/IEC 13818-2.

3.44 **display aspect ratio**: The ratio of height divided by width (in spatial measurement units such as centimetres) of the intended display.

3.45 **display order**: The order in which the decoded pictures are displayed. Normally this is the same order in which they were presented at the input of the encoder.

3.46 **display process**: The (non-normative) process by which reconstructed frames are displayed.

3.47 **dual-prime prediction**: A prediction mode in which two forward field-based predictions are averaged. The predicted block size is 16×16 luminance samples.

3.48 **editing**: The process by which one or more coded bitstreams are manipulated to produce a new coded bitstream. Conforming edited bitstreams must meet the requirements defined in Rec. ITU-T H.262 | ISO/IEC 13818-2.

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

3.50 **encoding (process)**: A process, not specified in Rec. ITU-T H.262 | ISO/IEC 13818-2, that reads a stream of input pictures and produces a valid coded bitstream as defined in Rec. ITU-T H.262 | ISO/IEC 13818-2.

3.51 **enhancement layer**: A relative reference to a layer (above the base layer) in a scalable hierarchy. For all forms of scalability, its decoding process can be described by reference to the lower layer decoding process and the appropriate additional decoding process for the enhancement layer itself.

3.52 **fast forward playback**: The process of displaying a sequence, or parts of a sequence, of pictures in display-order faster than real-time.

3.53 **fast reverse playback**: The process of displaying the picture sequence in the reverse of display order faster than real-time.

3.54 **field**: For an interlaced video signal, a "field" is the assembly of alternate lines of a frame. Therefore an interlaced frame is composed of two fields, a top field and a bottom field.

3.55 **field-based prediction**: A prediction mode using only one field of the reference frame. The predicted block size is 16×16 luminance samples.

3.56 **field period**: The reciprocal of twice the frame rate.

3.57 **field picture; field structure picture**: A field structure picture is a coded picture with picture_structure is equal to "Top field" or "Bottom field".

3.58 **flag**: A one bit integer variable which may take one of only two values (zero and one).

3.59 **forbidden**: The term "forbidden" when used in the clauses defining the coded bitstream indicates that the value shall never be used. This is usually to avoid emulation of start codes.

3.60 **forced updating**: The process by which macroblocks are intra-coded from time-to-time to ensure that mismatch errors between the inverse DCT processes in encoders and decoders cannot build up excessively.

3.61 **forward compatibility**: A newer coding standard is forward compatible with an older coding standard if decoders designed to operate with the newer coding standard are able to decode bitstreams of the older coding standard.

3.62 **forward motion vector**: A motion vector that is used for motion compensation from a reference frame or reference field at an earlier time in display order.

3.63 **forward prediction**: Prediction from the past reference frame (field).

3.64 **frame**: A frame contains lines of spatial information of a video signal. For progressive video, these lines contain samples starting from one time instant and continuing through successive lines to the bottom of the frame. For interlaced video, a frame consists of two fields, a top field and a bottom field. One of these fields will commence one field period later than the other.

3.65 **frame-based prediction**: A prediction mode using both fields of the reference frame.

3.66 **frame period**: The reciprocal of the frame rate.

3.67 **frame picture; frame structure picture**: A frame structure picture is a coded picture with picture_structure is equal to "Frame".

3.68 **frame rate**: The rate at which frames are output from the decoding process.

3.69 **future reference frame (field)**: A future reference frame (field) is a reference frame (field) that occurs at a later time than the current picture in display order.

3.70 **frame re-ordering**: The process of re-ordering the reconstructed frames when the coded order is different from the display order. Frame re-ordering occurs when B-frames are present in a bitstream. There is no frame re-ordering when decoding low delay bitstreams.

3.71 **group of pictures**: A notion defined only in ISO/IEC 11172-2 (MPEG-1 Video). In Rec. ITU-T H.262 | ISO/IEC 13818-2, a similar functionality can be achieved by means of inserting group of pictures headers.

3.72 **header**: A block of data in the coded bitstream containing the coded representation of a number of data elements pertaining to the coded data that follow the header in the bitstream.

3.73 **hybrid scalability**: Hybrid scalability is the combination of two (or more) types of scalability.

3.74 **interlace**: The property of conventional television frames where alternating lines of the frame represent different instances in time. In an interlaced frame, one of the fields is meant to be displayed first. This field is called the first field. The first field can be the top field or the bottom field of the frame.

3.75 **I-field picture**: A field structure I-picture.

3.76 **I-frame picture**: A frame structure I-picture.

3.77 **I-picture; intra-coded picture**: A picture coded using information only from itself.

3.78 **intra coding**: Coding of a macroblock or picture that uses information only from that macroblock or picture.

3.78.1 **Inverse DCT, IDCT**: Inverse discrete cosine transform, as defined in Annex A.

3.79 **level**: A defined set of constraints on the values which may be taken by the parameters of Rec. ITU-T H.262 | ISO/IEC 13818-2 within a particular profile. A profile may contain one or more levels. In a different context, level is the absolute value of a non-zero coefficient (see "run").

3.80 **layer**: In a scalable hierarchy denotes one out of the ordered set of bitstreams and (the result of) its associated decoding process (implicitly including decoding of **all** layers below this layer).

3.81 **layer bitstream**: A single bitstream associated to a specific layer (always used in conjunction with layer qualifiers, e. g. "enhancement layer bitstream").

3.82 **lower layer**: A relative reference to the layer immediately below a given enhancement layer (implicitly including decoding of **all** layers below this enhancement layer).

3.83 **luminance component**: A matrix, block or single sample representing a monochrome representation of the signal and related to the primary colours in the manner defined in the bitstream. The symbol used for luminance is Y.

3.84 **Mbit**: 1 000 000 bits.

3.85 **macroblock**: The four 8 by 8 blocks of luminance data and the two (for 4:2:0 chrominance format), four (for 4:2:2 chrominance format) or eight (for 4:4:4 chrominance format) corresponding 8 by 8 blocks of chrominance data coming from a 16 by 16 section of the luminance component of the picture. Macroblock is sometimes used to refer to the sample data and sometimes to the coded representation of the sample values and other data elements defined in the macroblock header of the syntax defined in Rec. ITU-T H.262 | ISO/IEC 13818-2. The usage is clear from the context.

3.86 **motion compensation**: The use of motion vectors to improve the efficiency of the prediction of sample values. The prediction uses motion vectors to provide offsets into the past and/or future reference frames or reference fields containing previously decoded sample values that are used to form the prediction error.

3.87 **motion estimation**: The process of estimating motion vectors during the encoding process.

3.88 **motion vector**: A two-dimensional vector used for motion compensation that provides an offset from the coordinate position in the current picture or field to the coordinates in a reference frame or reference field.

3.89 **non-intra coding**: Coding of a macroblock or picture that uses information both from itself and from macroblocks and pictures occurring at other times.

3.90 **opposite parity**: The opposite parity of top is bottom, and vice versa.

3.91 **P-field picture**: A field structure P-picture.

3.92 **P-frame picture**: A frame structure P-picture.

3.93 **P-picture; predictive-coded picture**: A picture that is coded using motion compensated prediction from past reference fields or frame.

3.94 **parameter**: A variable within the syntax of Rec. ITU-T H.262 | ISO/IEC 13818-2 which may take one of a range of values. A variable which can take one of only two values is called a flag.

3.95 **parity (of field)**: The parity of a field can be top or bottom.

3.96 **past reference frame (field)**: A past reference frame (field) is a reference frame (field) that occurs at an earlier time than the current picture in display order.

3.97 **picture**: Source, coded or reconstructed image data. A source or reconstructed picture consists of three rectangular matrices of 8-bit numbers representing the luminance and two chrominance signals. A "coded picture" is defined in 3.21 of Rec. ITU-T H.262 | ISO/IEC 13818-2. For progressive video, a picture is identical to a frame, while for interlaced video, a picture can refer to a frame, or the top field or the bottom field of the frame depending on the context.

3.98 **picture data**: In the VBV operations, picture data is defined as all the bits of the coded picture, all the header(s) and user data immediately preceding it if any (including any stuffing between them) and all the stuffing following it, up to (but not including) the next start code, except in the case where the next start code is an end of sequence code, in which case it is included in the picture data.

3.99 **prediction**: The use of a predictor to provide an estimate of the sample value or data element currently being decoded.

3.100 **prediction error**: The difference between the actual value of a sample or data element and its predictor.

3.101 **predictor**: A linear combination of previously decoded sample values or data elements.

3.102 **profile**: A defined subset of the syntax of Rec. ITU-T H.262 | ISO/IEC 13818-2.

NOTE – In Rec. ITU-T H.262 | ISO/IEC 13818-2, the word "profile" is used as defined above. It should not be confused with other definitions of "profile" and in particular it does not have the meaning that is defined by ISO/IEC JTC1 Special Group on Functional Standardization.

3.103 **progressive**: The property of film frames where all the samples of the frame represent the same instances in time.

3.104 **quantization matrix**: A set of sixty-four 8-bit values used by the dequantizer.

3.105 **quantized DCT coefficients**: DCT coefficients before dequantization. A variable length coded representation of quantized DCT coefficients is transmitted as part of the coded video bitstream.

3.106 **quantizer scale**: A scale factor coded in the bitstream and used by the decoding process to scale the dequantization.

3.107 **random access**: The process of beginning to read and decode the coded bitstream at an arbitrary point.

3.108 **reconstructed frame**: A reconstructed frame consists of three rectangular matrices of 8-bit numbers representing the luminance and two chrominance signals. A reconstructed frame is obtained by decoding a coded frame.

3.109 **reconstructed picture**: A reconstructed picture is obtained by decoding a coded picture. A reconstructed picture is either a reconstructed frame (when decoding a frame picture), or one field of a reconstructed frame (when decoding a field picture). If the coded picture is a field picture, then the reconstructed picture is the top field or the bottom field of the reconstructed frame.

3.110 **reference field**: A reference field is one field of a reconstructed frame. Reference fields are used for forward and backward prediction when P-pictures and B-pictures are decoded. Note that when field P-pictures are decoded, prediction of the second field P-picture of a coded frame uses the first reconstructed field of the same coded frame as a reference field.

3.111 reference frame: A reference frame is a reconstructed frame that was coded in the form of a coded I-frame or a coded P-frame. Reference frames are used for forward and backward prediction when P-pictures and B-pictures are decoded.

3.112 re-ordering delay: A delay in the decoding process that is caused by frame re-ordering.

3.113 reserved: The term "reserved" when used in the clauses defining the coded bitstream, indicates that the value may be used in the future for ITU-T | ISO/IEC defined extensions.

3.114 sample aspect ratio (SAR): This specifies the relative distance between samples. It is defined (for the purposes of Rec. ITU-T H.262 | ISO/IEC 13818-2), as the vertical displacement of the lines of luminance samples in a frame divided by the horizontal displacement of the luminance samples. Thus, its units are (metres per line) ÷ (metres per sample).

3.115 scalable hierarchy: Coded video data consisting of an ordered set of more than one video bitstream.

3.116 scalability: Scalability is the ability of a decoder to decode an ordered set of bitstreams to produce a reconstructed sequence. Moreover, useful video is output when subsets are decoded. The minimum subset that can thus be decoded is the first bitstream in the set which is called the base layer. Each of the other bitstreams in the set is called an enhancement layer. When addressing a specific enhancement layer, "lower layer" refer to the bitstream which precedes the enhancement layer.

3.117 side information: Information in the bitstream necessary for controlling the decoder.

3.118 16 × 8 prediction: A prediction mode similar to field-based prediction but where the predicted block size is 16 × 8 luminance samples.

3.119 run: The number of zero coefficients preceding a non-zero coefficient, in the scan order. The absolute value of the non-zero coefficient is called "level".

3.120 saturation: Limiting a value that exceeds a defined range by setting its value to the maximum or minimum of the range as appropriate.

3.121 skipped macroblock: A macroblock for which no data is encoded.

3.122 slice: A consecutive series of macroblocks which are all located in the same horizontal row of macroblocks.

3.123 SNR scalability: A type of scalability where the enhancement layer(s) contain only coded refinement data for the DCT coefficients of the lower layer.

3.124 source; input: Term used to describe the video material or some of its attributes before encoding.

3.125 spatial prediction: Prediction derived from a decoded frame of the lower layer decoder used in spatial scalability.

3.126 spatial scalability: A type of scalability where an enhancement layer also uses predictions from sample data derived from a lower layer without using motion vectors. The layers can have different frame sizes, frame rates or chrominance formats.

3.127 start codes (system and video): 32-bit codes embedded in that coded bitstream that are unique. They are used for several purposes including identifying some of the structures in the coding syntax.

3.128 stuffing (bits); stuffing (bytes): Code-words that may be inserted into the coded bitstream that are discarded in the decoding process. Their purpose is to increase the bit rate of the stream which would otherwise be lower than the desired bit rate.

3.129 temporal prediction: Prediction derived from reference frames or fields other than those defined as spatial prediction.

3.130 temporal scalability: A type of scalability where an enhancement layer also uses predictions from sample data derived from a lower layer using motion vectors. The layers have identical frame size, and chrominance formats, but can have different frame rates.

3.131 top field: One of two fields that comprise a frame. Each line of a top field is spatially located immediately above the corresponding line of the bottom field.

3.132 top layer: The topmost layer (with the highest layer_id) of a scalable hierarchy.

3.133 variable bit rate: Operation where the bit rate varies with time during the decoding of a coded bitstream.

3.134 variable length coding (VLC): A reversible procedure for coding that assigns shorter code-words to frequent events and longer code-words to less frequent events.

3.135 video buffering verifier (VBV): A hypothetical decoder that is conceptually connected to the output of the encoder. Its purpose is to provide a constraint on the variability of the data rate that an encoder or editing process may produce.

3.136 video sequence: The highest syntactic structure of coded video bitstreams. It contains a series of one or more coded frames.

3.137 xxx profile decoder: Decoder able to decode one or a scalable hierarchy of bitstreams of which the top layer conforms to the specifications of the xxx profile (with xxx being any of the defined Profile names).

3.138 xxx profile scalable hierarchy: Set of bitstreams of which the top layer conforms to the specifications of the xxx profile.

3.139 xxx profile bitstream: A bitstream of a scalable hierarchy with a profile indication corresponding to xxx. Note that this bitstream is only decodable together with all its lower layer bitstreams (unless it is a base layer bitstream).

3.140 zigzag scanning order: A specific sequential ordering of the DCT coefficients from (approximately) the lowest spatial frequency to the highest.

4 Abbreviations and symbols

The mathematical operators used to describe this Specification are similar to those used in the C programming language. However, integer divisions with truncation and rounding are specifically defined. Numbering and counting loops generally begin from zero.

4.1 Arithmetic operators

+	Addition
–	Subtraction (as a binary operator) or negation (as a unary operator)
++	Increment, i.e. *x*++ is equivalent to x = x + 1
––	Decrement, i.e. *x*–– is equivalent to x = x – 1
× *	Multiplication
^	Power
/	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.
//	Integer division with rounding to the nearest integer. Half-integer values are rounded away from zero unless otherwise specified. For example 3//2 is rounded to 2, and –3//2 is rounded to –2.
DIV	Integer division with truncation of the result toward minus infinity. For example 3 DIV 2 is rounded to 1, and –3 DIV 2 is rounded to –2.
÷	Used to denote division in mathematical equations where no truncation or rounding is intended.
%	Modulus operator. Defined only for positive numbers.
Sign( )	$\mathrm{Sign}(x) = \begin{cases} 1 & x > 0 \\ 0 & x == 0 \\ -1 & x < 0 \end{cases}$
Abs( )	$\mathrm{Abs}(x) = \begin{cases} x & x >= 0 \\ -x & x < 0 \end{cases}$
$\sum_{i=a}^{i<b} f(i)$	The summation of the $f(i)$ with i taking integral values from a up to, but not including b.
Floor( )	the largest integer less than or equal to the argument.
Round( )	Sign(x) * Floor(Abs(x) + 0.5), for an argument x.

4.2 Logical operators

||	Logical OR
&&	Logical AND
!	Logical NOT

4.3 Relational operators

>	Greater than
>=	Greater than or equal to
<	Less than
<=	Less than or equal to
==	Equal to
!=	Not equal to
max [, … ,]	The maximum value in the argument list
min [, … ,]	The minimum value in the argument list

4.4 Bitwise operators

&	AND
|	OR
>>	Shift right with sign extension
<<	Shift left with zero fill

4.5 Assignment

= Assignment operator

4.6 Mnemonics

The following mnemonics are defined to describe the different data types used in the coded bitstream.

bslbf Bit string, left bit first, where "left" is the order in which bit strings are written in this Specification. Bit strings are generally written as a string of 1s and 0s within single quote marks, e.g. '1000 0001'. Blanks within a bit string are for ease of reading and have no significance. For convenience, large strings are occasionally written in hexadecimal; in this case, conversion to a binary in the conventional manner will yield the value of the bit string. Thus, the left most hexadecimal digit is first and in each hexadecimal digit the most significant of the four bits is first.

uimsbf Unsigned integer, most significant bit first.

simsbf Signed integer, in two's complement format, most significant (sign) bit first.

vlclbf Variable length code, left bit first, where "left" refers to the order in which the VLC codes are written. The byte order of multibyte words is the most significant byte first.

In the clauses describing the syntax, any syntactic element that can only take positive or unsigned values (such as a flag that can be equal to 0 or 1) is described with the mnemonic 'uimsbf'. If the syntactic element can have a negative value, it is described with the mnemonic 'simsbf'. If the syntactic element has a constant value (e.g. marker_bit) then it is described with the mnemonic 'bslbf'. If the syntactic element represents a variable-length code, it is described with the mnemonic 'vlclbf'.

4.7 Constants

π 3.141 592 653 58...

e 2.718 281 828 45...

5 Conventions

5.1 Method of describing bitstream syntax

The bitstream retrieved by the decoder is described in 6.2. Each data item in the bitstream is in bold type. It is described by its name, its length in bits, and a mnemonic for its type and order of transmission.

The action caused by a decoded data element in a bitstream depends on the value of that data element and on data elements previously decoded. The decoding of the data elements and definition of the state variables used in their decoding are described in 6.3. The following constructs are used to express the conditions when data elements are present, and are in normal type:

while (condition) {
    data_element
    . . .
}
	If the condition is true, then the group of data elements occurs next in the data stream. This repeats until the condition is not true.

do {
    data_element
    . . .
} while (condition)
	The data element always occurs at least once.
	The data element is repeated until the condition is not true.

if (condition) {
    data_element
    . . .
} else {
    data_element
    . . .
}
	If the condition is true, then the first group of data elements occurs next in the data stream.
	If the condition is not true, then the second group of data elements occurs next in the data stream.

for (i = m; i < n; i++) {
    data_element
    . . .
}
	The group of data elements occurs (m – n) times. Conditional constructs within the group of data elements may depend on the value of the loop control variable i, which is set to zero for the first occurrence, incremented by one for the second occurrence, and so forth.

/* comment ... */	Explanatory comment that may be deleted entirely without in any way altering the syntax.

This syntax uses the 'C-code' convention that a variable or expression evaluating to a non-zero value is equivalent to a condition that is true and a variable or expression evaluating to a zero value is equivalent to a condition that is false. In many cases a literal string is used in a condition. For example:

if (scalable_mode == "spatial scalability") …

In such cases the literal string is that used to describe the value of the bitstream element in 6.3. In this example, we see that "spatial scalability" is defined in Table 6-10 to be represented by the two bit binary number '01'.

As noted, the group of data elements may contain nested conditional constructs. For compactness, the {} are omitted when only one data element follows:

data_element [n] data_element [n] is the (n + 1)-th element of an array of data.

data_element [m][n] data_element [m][n] is the (m + 1, n + 1)-th element of a two-dimensional array of data.

data_element [l][m][n] data_element [l][m][n] is the (l + 1, m + 1, n + 1)-th element of a three-dimensional array of data.

While the syntax is expressed in procedural terms, it should not be assumed that 6.2 implements a satisfactory decoding procedure. In particular, it defines a correct and error-free input bitstream. Actual decoders must include means to look for start codes in order to begin decoding correctly, and to identify errors, erasures or insertions while decoding. The methods to identify these situations, and the actions to be taken, are not standardized.

5.2 Definition of functions

Several utility functions for picture coding algorithm are defined as follows.

5.2.1 Definition of bytealigned() function

The function bytealigned () returns 1 if the current position is on a byte boundary, that is the next bit in the bitstream is the first bit in a byte. Otherwise it returns 0.

5.2.2 Definition of nextbits() function

The function nextbits () permits comparison of a bit string with the next bits to be decoded in the bitstream.

5.2.3 Definition of next_start_code() function

The next_start_code() function removes any zero bit and zero byte stuffing and locates the next start code.

next_start_code() {	No. of bits	Mnemonic
while (!bytealigned())		
zero_bit	1	'0'
while (nextbits() != '0000 0000 0000 0000 0000 0001')		
zero_byte	8	'0000 0000'
}		

This function checks whether the current position is byte aligned. If it is not, zero stuffing bits are present. After that any number of zero stuffing bytes may be present before the start code. Therefore, start codes are always byte aligned and may be preceded by any number of zero stuffing bits.

5.3 Reserved, forbidden and marker_bit

The terms "reserved" and "forbidden" are used in the description of some values of several fields in the coded bitstream.

The term "reserved" indicates that the value may be used in the future for ITU-T | ISO/IEC defined extensions.

The term "forbidden" indicates a value that shall never be used (usually in order to avoid emulation of start codes).

The term "marker_bit" indicates a one bit integer in which the value zero is forbidden (and it therefore shall have the value '1'). These marker bits are introduced at several points in the syntax to avoid start code emulation.

5.4 Arithmetic precision

In order to reduce discrepancies between implementations of this Specification, the following rules for arithmetic operations are specified:

a) Where an arithmetically-precise result is not fully specified, such as in the calculation of the IDCT, the precision shall be sufficient so that significant errors do not occur in the final integer values.

b) Where ranges of values are given by a colon, the end points are included if a bracket is present, and excluded if the 'less than' (<) and 'greater than' (>) characters are used. For example, [a : b > means from *a* to *b*, including *a* but excluding *b*.

6 Video bitstream syntax and semantics

6.1 Structure of coded video data

Coded video data consists of an ordered set of video bitstreams, called layers. If there is only one layer, the coded video data is called non-scalable video bitstream. If there are two layers or more, the coded video data is called a scalable hierarchy.

The first layer (of the ordered set) is called base layer, and it can always be decoded independently. See 7.1 to 7.6 and 7.12 for a description of the decoding process for the base layer, except in the case of Data partitioning, described in 7.10.

Other layers are called enhancement layers, and can only be decoded together with all the lower layers (previous layers in the ordered set), starting with the base layer. See 7.7 to 7.11 for a description of the decoding process for scalable hierarchy.

See Rec. ITU-T H.222.0 | ISO/IEC 13818-1 [6] for a description of the way layers may be multiplexed together.

The base layer of a scalable hierarchy may conform to this Specification or to other standards such as ISO/IEC 11172-2. See details in 7.7 to 7.11. Enhancement layers shall conform to this Specification.

In all cases apart from Data partitioning, the base layer does not contain a sequence_scalable_extension(). Enhancement layers always contain sequence_scalable_extension().

In general, the video bitstream can be thought of as a syntactic hierarchy in which syntactic structures contain one or more subordinate structures. For instance, the structure "picture_data()" contains one or more of the syntactic structure "slice()" which in turn contains one or more of the structure "macroblock()".

This structure is very similar to that used in ISO/IEC 11172-2.

6.1.1 Video sequence

The highest syntactic structure of the coded video bitstream is the video sequence.

A video sequence commences with a sequence header which may optionally be followed by a group of pictures header and then by one or more coded frames. The order of the coded frames in the coded bitstream is the order in which the decoder processes them, but not necessarily in the correct order for display. The video sequence is terminated by a sequence_end_code. At various points in the video sequence, a particular coded frame may be preceded by either a repeat sequence header or a group of pictures header or both. (In the case that both a repeat sequence header and a group of pictures header immediately precede a particular picture, the group of pictures header shall follow the repeat sequence header.)

6.1.1.1 Progressive and interlaced sequences

This Specification deals with coding of both progressive and interlaced sequences.

The output of the decoding process, for interlaced sequences, consists of a series of reconstructed fields that are separated in time by a field period. The two fields of a frame may be coded separately (field-pictures). Alternatively the two fields may be coded together as a frame (frame pictures). Both frame pictures and field pictures may be used in a single video sequence.

In progressive sequences each picture in the sequence shall be a frame picture. The sequence, at the output of the decoding process, consists of a series of reconstructed frames that are separated in time by a frame period.

6.1.1.2 Frame

A frame consists of three rectangular matrices of integers: a luminance matrix (Y), and two chrominance matrices (Cb and Cr).

The relationship between these Y, Cb and Cr components and the primary (analogue) Red, Green and Blue Signals (E'_R, E'_G and E'_B), the chromaticity of these primaries and the transfer characteristics of the source frame may be specified in the bitstream (or specified by some other means). This information does not affect the decoding process.

6.1.1.3 Field

A field consists of every other line of samples in the three rectangular matrices of integers representing a frame.

A frame is the union of a top field and a bottom field. The top field is the field that contains the top-most line of each of the three matrices. The bottom field is the other one.

6.1.1.4 Picture

A coded picture is made of a picture header, the optional extensions immediately following it and the following picture data. A coded picture may be a coded frame or a coded field.

An I-frame picture or a pair of field pictures, where the first field picture is an I-picture and the second field picture is an I-picture or a P-picture, is called a coded I-frame.

A P-frame picture or a pair of P-field pictures is called a coded P-frame.

A B-frame picture or a pair of B-field pictures is called a coded B-frame.

A coded I-frame, a coded P-frame or a coded B-frame is called a coded frame.

A reconstructed picture is obtained by decoding a coded picture, i.e. a picture header, the optional extensions immediately following it, and the picture data. A coded picture may be a frame picture or a field picture. A reconstructed picture is either a reconstructed frame (when decoding a frame picture), or one field of a reconstructed frame (when decoding a field picture).

6.1.1.4.1 Field pictures

If field pictures are used, then they shall occur in pairs (one top field followed by one bottom field, or one bottom field followed by one top field) and together constitute a coded frame. The two field pictures that comprise a coded frame shall be encoded in the bitstream in the order in which they shall occur at the output of the decoding process.

When the first picture of the coded frame is a P-field picture, then the second picture of the coded frame shall also be a P-field picture. Similarly when the first picture of the coded frame is a B-field picture the second picture of the coded frame shall also be a B-field picture.

When the first picture of the coded frame is a I-field picture, then the second picture of the frame shall be either an I-field picture or a P-field picture. If the second picture is a P-field picture, then certain restrictions apply (see 7.6.3.5).

6.1.1.4.2 Frame pictures

When coding interlaced sequences using frame pictures, the two fields of the frame shall be interleaved with one another and then the entire frame is coded as a single frame picture.

6.1.1.5 Picture types

There are three types of pictures that use different coding methods:

- an **Intra-coded (I) picture** is coded using information only from itself;
- a **Predictive-coded (P) picture** is a picture which is coded using motion compensated prediction from a past reference frame or past reference field;
- a **Bidirectionally predictive-coded (B) picture** is a picture which is coded using motion compensated prediction from a past and/or future reference frame(s).

6.1.1.6 Sequence header

A video sequence header commences with a sequence_header_code and is followed by a series of data elements. In this Specification, sequence_header() shall be followed by sequence_extension() which includes further parameters beyond those used by ISO/IEC 11172-2. When sequence_extension() is present, the syntax and semantics defined in ISO/IEC 11172-2 do not apply, and the present Specification applies.

In repeat sequence headers all of the data elements with the permitted exception of those defining the quantization matrices (load_intra_quantiser_matrix, load_non_intra_quantiser_matrix and optionally intra_quantiser_matrix and non_intra_quantiser_matrix) shall have the same values as in the first sequence header. The quantization matrices may be redefined each time that a sequence header occurs in the bitstream (note that quantization matrices may also be updated using quant_matrix_extension()).

All of the data elements in the sequence_extension() that follows a repeat sequence_header() shall have the same values as in the first sequence_extension().

If a sequence_scalable_extension() occurs after the first sequence_header() all subsequent sequence headers shall be followed by sequence_scalable_extension() in which all data elements are the same as in the first sequence_scalable_extension(). Conversely if no sequence_scalable_extension() occurs between the first sequence_header() and the first picture_header(), then sequence_scalable_extension() shall not occur in the bitstream.

If a sequence_display_extension() occurs after the first sequence_header() all subsequent sequence headers shall be followed by sequence_display_extension() in which all data elements are the same as in the first sequence_display_extension(). Conversely if no sequence_display_extension() occurs between the first sequence_header() and the first picture_header(), then sequence_display_extension() shall not occur in the bitstream.

Repeating the sequence header allows the data elements of the initial sequence header to be repeated in order that random access into the video sequence is possible.

In the coded bitstream, the first picture following a sequence header or a repeated sequence header shall be either an I-picture or a P-picture, but not a B-picture. In the case that an interlaced frame is coded as two separate field pictures, a repeat sequence header shall not precede the second of these two field pictures.

If a bitstream is edited so that all of the data preceding any of the repeat sequence headers is removed (or alternatively random access is made to that sequence header), then the resulting bitstream shall be a legal bitstream that complies with this Specification. In the case that the first picture of the resulting bitstream is a P-picture, it is possible that it will contain non-intra macroblocks. Since the reference picture(s) required by the decoding process are not available, the reconstructed picture may not be fully defined. The time taken to fully refresh the entire frame depends on the refresh techniques employed.

6.1.1.7 I-pictures and group of pictures header

I-pictures are intended to assist random access into the sequence. Applications requiring random access, fast-forward playback, or fast reverse playback may use I-pictures relatively frequently.

I-pictures may also be used at scene cuts or other cases where motion compensation is ineffective.

Group of picture header is an optional header that can be used immediately before a coded I-frame to indicate to the decoder if the first consecutive B-pictures immediately following the coded I-frame can be reconstructed properly in the case of a random access. In effect, if the preceding reference frame is not available, those B-pictures, if any, cannot be reconstructed properly unless they only use backward prediction or intra coding. This is more precisely defined in the clause describing closed_gop and broken_link. A group of picture header also contains a time code information that is not used by the decoding process.

In the coded bitstream, the first coded frame following a group of pictures header shall be a coded I-frame.

6.1.1.8 4:2:0 format

In this format the Cb and Cr matrices shall be one half the size of the Y-matrix in both horizontal and vertical dimensions. The Y-matrix shall have an even number of lines and samples.

NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus, the total number of lines in the Y-matrix of an entire frame shall be divisible by four.

The luminance and chrominance samples are positioned as shown in Figure 6-1.

In order to further specify the organization, Figures 6-2 and 6-3 show the vertical and temporal positioning of the samples in an interlaced frame. Figure 6-4 shows the vertical and temporal positioning of the samples in a progressive frame.

In each field of an interlaced frame, the chrominance samples do not lie (vertically) midway between the luminance samples of the field, this is so that the spatial location of the chrominance samples in the frame is the same whether the frame is represented as a single frame picture or two field pictures.

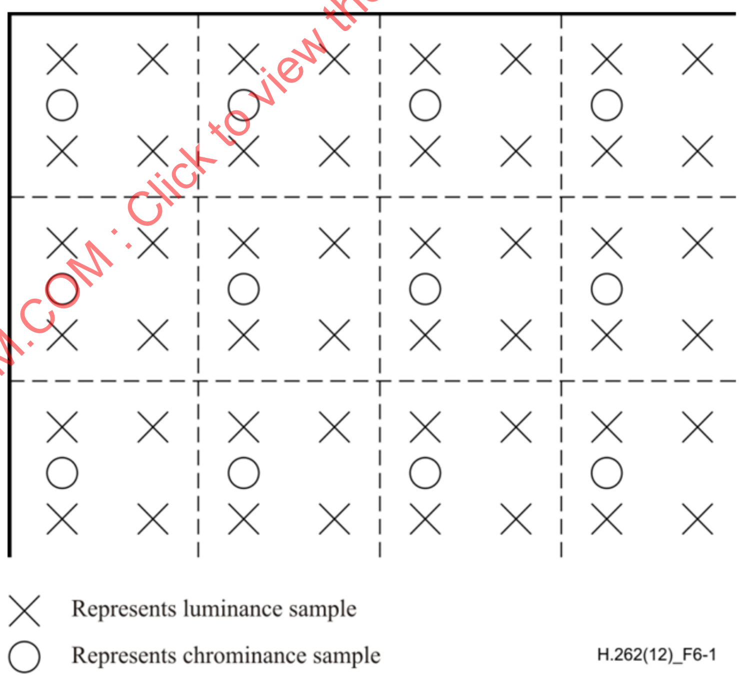


Figure 6-1 – The position of luminance and chrominance samples – 4:2:0 data

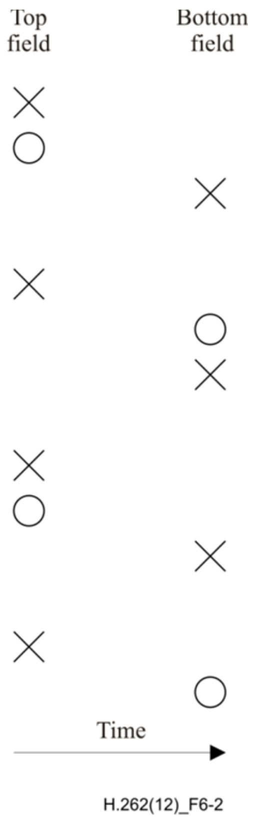


Figure 6-2 – Vertical and temporal positions of samples in an interlaced frame with top_field_first = 1

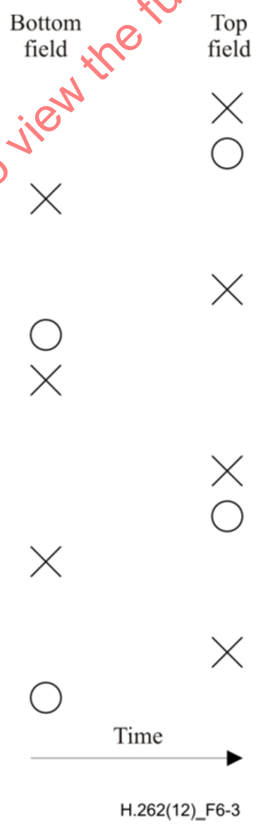


Figure 6-3 – Vertical and temporal positions of samples in an interlaced frame with top_loop_first = 0

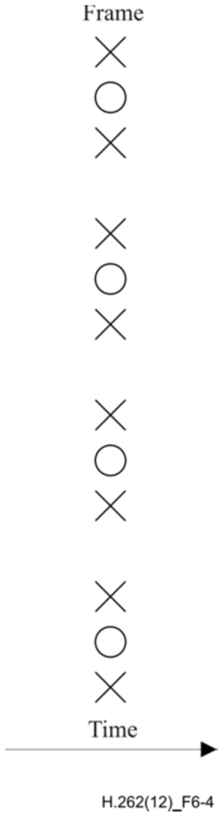


Figure 6-4 – Vertical and temporal positions of samples in a progressive frame

6.1.1.9 4:2:2 format

In this format the Cb and Cr matrices shall be one half the size of the Y-matrix in the horizontal dimension and the same size as the Y-matrix in the vertical dimension. The Y-matrix shall have an even number of samples.

NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus the total number of lines in the Y-matrix of an entire frame shall be divisible by two.

The luminance and chrominance samples are positioned as shown in Figure 6-5.

In order to clarify the organization, Figure 6-6 shows the (vertical) positioning of the samples when the frame is separated into two fields.

6.1.1.10 4:4:4 format

In this format the Cb and Cr matrices shall be the same size as the Y-matrix in the horizontal and the vertical dimensions.

NOTE – When interlaced frames are coded as field pictures, the picture reconstructed from each of these field pictures shall have a Y-matrix with half the number of lines as the corresponding frame. Thus the total number of lines in the Y-matrix of an entire frame shall be divisible by two.

The luminance and chrominance samples are positioned as shown in Figures 6-6 and 6-7.

6.1.1.11 Frame re-ordering

When the sequence contains coded B-frames, the number of consecutive coded B-frames is variable and unbounded. The first coded frame after a sequence header shall not be a B-frame.

A sequence may contain no coded P-frames. A sequence may also contain no coded I-frames in which case some care is required at the start of the sequence and within the sequence to effect both random access and error recovery.

The order of the coded frames in the bitstream, also called coded order, is the order in which a decoder reconstructs them. The order of the reconstructed frames at the output of the decoding process, also called the display order, is not always the same as the coded order and this subclause defines the rules of frame re-ordering that shall happen within the decoding process.

When the sequence contains no coded B-frames, the coded order is the same as the display order. This is true in particular always when low_delay is one.

When B-frames are present in the sequence, re-ordering is performed according to the following rules:

- If the current frame in coded order is a B-frame, the output frame is the frame reconstructed from that B-frame.
- If the current frame in coded order is a I-frame or P-frame, the output frame is the frame reconstructed from the previous I-frame or P-frame if one exists. If none exists, at the start of the sequence, no frame is output.

The frame reconstructed from the final I-frame or P-frame is output immediately after the frame reconstructed when the last coded frame in the sequence was removed from the VBV buffer.

The following is an example of frames taken from the beginning of a video sequence. In this example there are two coded B-frames between successive coded P-frames and also two coded B-frames between successive coded I- and P-frames and all pictures are frame pictures. Frame '1I' is used to form a prediction for frame '4P'. Frames '4P' and '1I' are both used to form predictions for frames '2B' and '3B'. Therefore the order of coded frames in the coded sequence shall be '1I', '4P', '2B', '3B'. However, the decoder shall display them in the order '1I', '2B', '3B', '4P'.

At the encoder input:

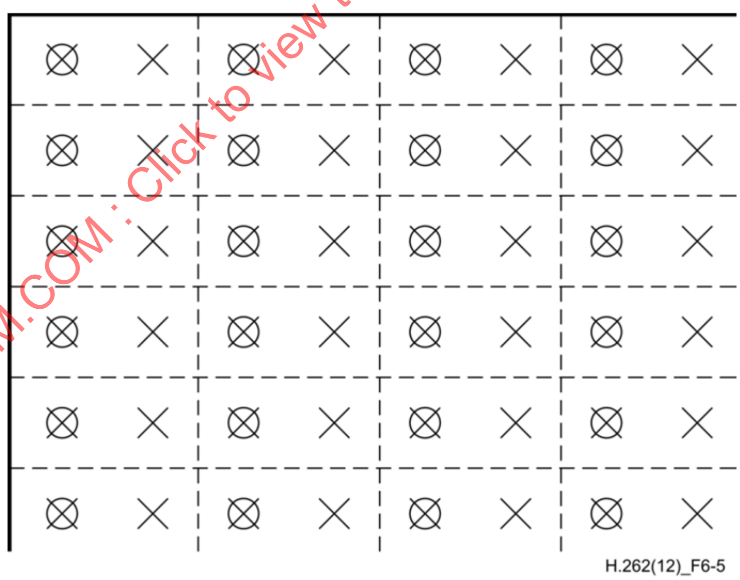
1	2	3	4	5	6	7	8	9	10	11	12	13
I	B	B	P	B	B	P	B	B	I	B	B	P

At the encoder output, in the coded bitstream, and at the decoder input:

1	4	2	3	7	5	6	10	8	9	13	11	12
I	P	B	B	P	B	B	I	B	B	P	B	B

At the decoder output:

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



× Represents luminance sample

○ Represents chrominance sample

Figure 6-5 – The position of luminance and chrominance samples – 4:2:2 data

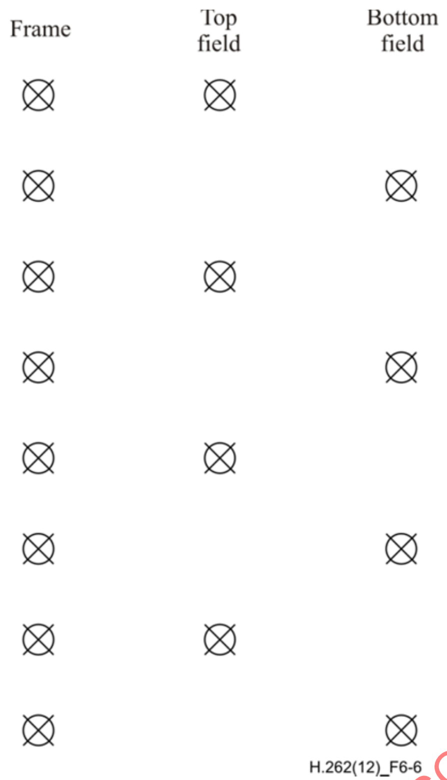


Figure 6-6 – Vertical positions of samples with 4:2:2 and 4:4:4 data

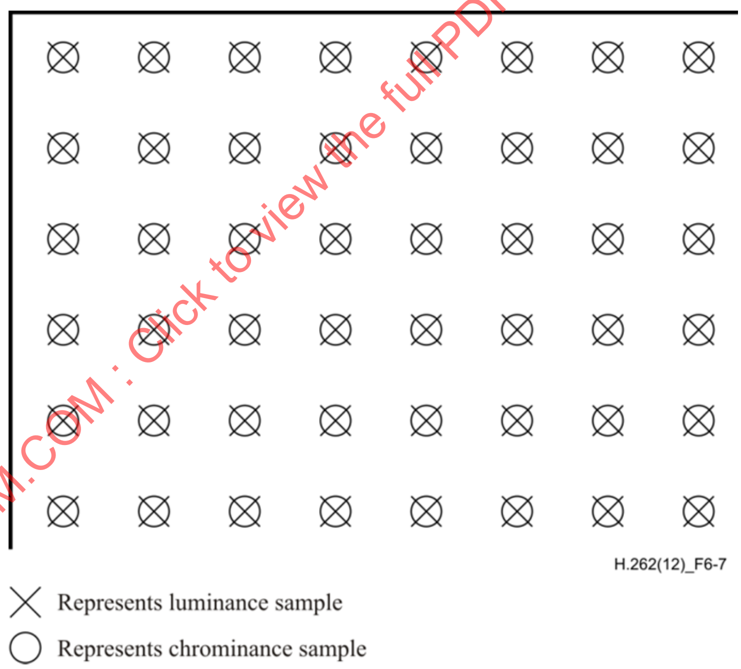


Figure 6-7 – The position of luminance and chrominance samples – 4:4:4 data

6.1.2 Slice

A **slice** is a series of an arbitrary number of consecutive macroblocks. The first and last macroblocks of a slice shall not be skipped macroblocks. Every slice shall contain at least one macroblock. Slices shall not overlap. The position of slices may change from picture to picture.

The first and last macroblock of a slice shall be in the same horizontal row of macroblocks.

Slices shall occur in the bitstream in the order in which they are encountered, starting at the upper-left of the picture and proceeding by raster-scan order from left to right and top to bottom (illustrated in Figures 6-8 and 6-9 as alphabetical order).

6.1.2.1 The general slice structure

In the most general case it is not necessary for the slices to cover the entire picture. Figure 6-8 shows this case. Those areas that are not enclosed in a slice are not encoded and no information is encoded for such areas (in the specific picture).

If the slices do not cover the entire picture, then it is a requirement that if the picture is subsequently used to form predictions, then predictions shall only be made from those regions of the picture that were enclosed in slices. It is the responsibility of the encoder to ensure this.

This Specification does not define what action a decoder shall take in the regions between the slices.

6.1.2.2 Restricted slice structure

In certain defined levels of defined profiles a restricted slice structure illustrated in Figure 6-9 shall be used. In this case every macroblock in the picture shall be enclosed in a slice.

Where a defined level of a defined profile requires that the slice structure obeys the restrictions detailed in this subclause, the term "restricted slice structure" may be used.

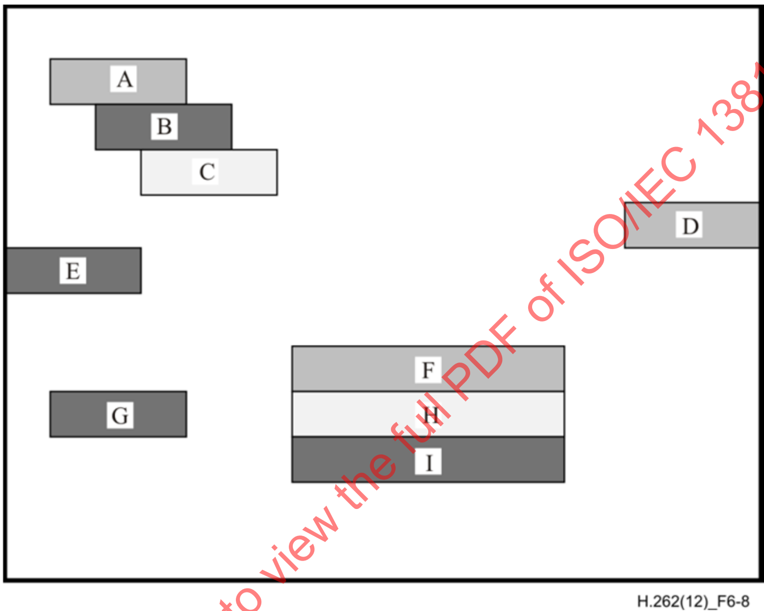


Figure 6-8 – The most general slice structure

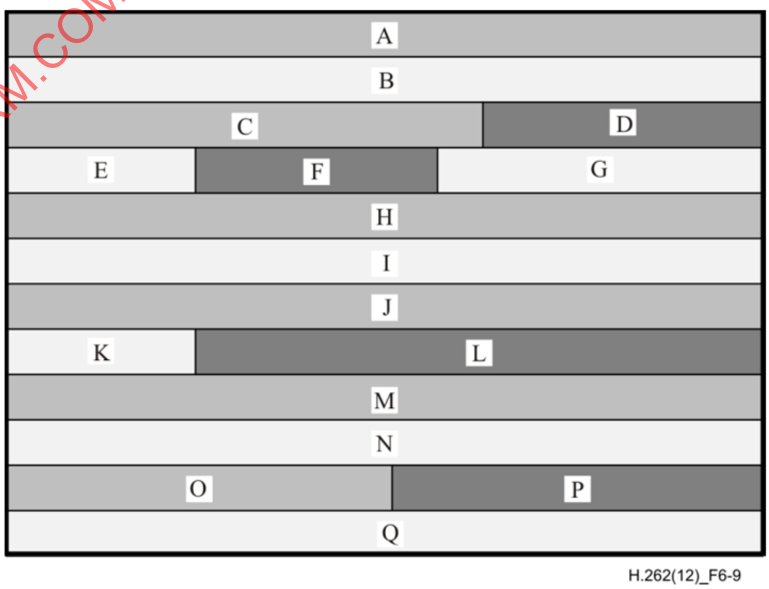


Figure 6-9 – Restricted slice structure

6.1.3 Macroblock

A **macroblock** contains a section of the luminance component and the spatially corresponding chrominance components. The term macroblock can either refer to source and decoded data or to the corresponding coded data elements. A skipped macroblock is one for which no information is transmitted (see 7.6.6). There are three chrominance formats for a macroblock, namely, 4:2:0, 4:2:2 and 4:4:4 formats. The orders of blocks in a macroblock shall be different for each different chrominance format and are illustrated below.

A 4:2:0 Macroblock consists of 6 blocks. This structure holds 4 Y, 1 Cb and 1 Cr Blocks and the block order is depicted in Figure 6-10.

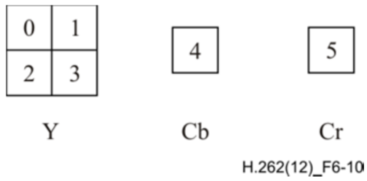


Figure 6-10 – 4:2:0 Macroblock structure

A 4:2:2 Macroblock consists of 8 blocks. This structure holds 4 Y, 2 Cb and 2 Cr Blocks and the block order is depicted in Figure 6-11.

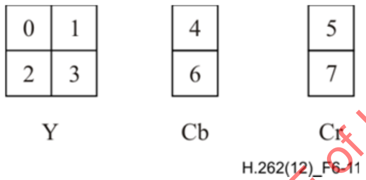


Figure 6-11 – 4:2:2 Macroblock structure

A 4:4:4 Macroblock consists of 12 blocks. This structure holds 4 Y, 4 Cb and 4 Cr Blocks and the block order is depicted in Figure 6-12.

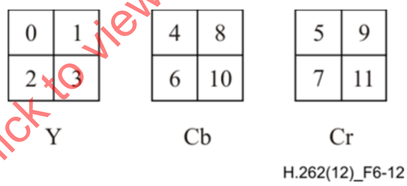


Figure 6-12 – 4:4:4 Macroblock structure

In frame pictures, where both frame and field DCT coding may be used, the internal organization within the macroblock is different in each case.

- In the case of frame DCT coding, each block shall be composed of lines from the two fields alternately. This is illustrated in Figure 6-13.
- In the case of field DCT coding, each block shall be composed of lines from only one of the two fields. This is illustrated in Figure 6-14.

In the case of chrominance blocks the structure depends upon the chrominance format that is being used. In the case of 4:2:2 and 4:4:4 formats (where there are two blocks in the vertical dimension of the macroblock) the chrominance blocks are treated in exactly the same manner as the luminance blocks. However, in the 4:2:0 format the chrominance blocks shall always be organized in frame structure for the purposes of DCT coding. It should, however, be noted that field based predictions may be made for these blocks which will, in the general case, require that predictions for 8×4 regions (after half-sample filtering) must be made.

In field pictures, each picture only contains lines from one of the fields. In this case each block consists of lines taken from successive lines in the picture as illustrated by Figure 6-13.

6.1.4 Block

The term "**block**" can refer either to source and reconstructed data or to the DCT coefficients or to the corresponding coded data elements.

When "block" refers to source and reconstructed data it refers to an orthogonal section of a luminance or chrominance component with the same number of lines and samples. There are 8 lines and 8 samples in the block.

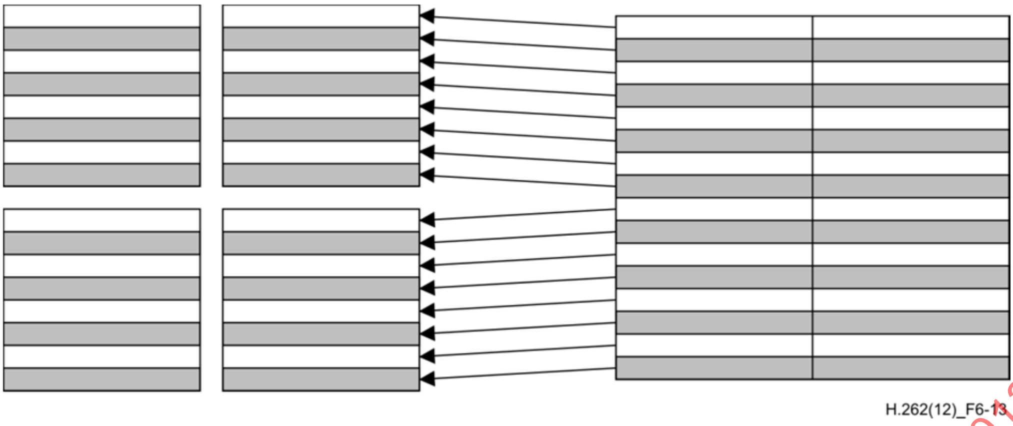


Figure 6-13 – Luminance macroblock structure in frame DCT coding

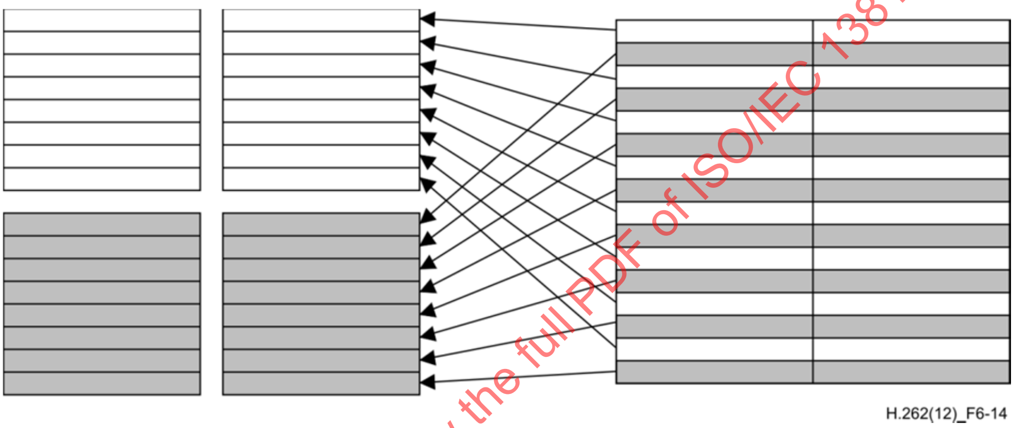


Figure 6-14 – Luminance macroblock structure in field DCT coding

6.2 Video bitstream syntax

6.2.1 Start codes

Start codes are specific bit patterns that do not otherwise occur in the video stream.

Each start code consists of a start code prefix followed by a start code value. The start code prefix is a string of twenty three bits with the value zero followed by a single bit with the value one. The start code prefix is thus the bit string '0000 0000 0000 0000 0000 0001'.

The start code value is an eight bit integer which identifies the type of start code. Most types of start code have just one start code value. However, slice_start_code is represented by many start code values, in this case the start code value is the slice_vertical_position for the slice.

All start codes shall be byte aligned. This shall be achieved by inserting bits with the value zero before the start code prefix such that the first bit of the start code prefix is the first (most significant) bit of a byte.

Table 6-1 defines the start code values for the start codes used in the video bitstream.

The use of the start codes is defined in the following syntax description with the exception of the sequence_error_code. The sequence_error_code has been allocated for use by a media interface to indicate where uncorrectable errors have been detected.

Table 6-1 – Start code values

Name	Start code value (hexadecimal)
picture_start_code	00
slice_start_code	01 through AF
reserved	B0
reserved	B1
user_data_start_code	B2
sequence_header_code	B3
sequence_error_code	B4
extension_start_code	B5
reserved	B6
sequence_end_code	B7
group_start_code	B8
system start codes (Note)	B9 through FF
NOTE – System start codes are defined in Part 1 of this Specification.	

6.2.2 Video Sequence

video_sequence() {	No. of bits	Mnemonic
next_start_code()		
sequence_header()		
if (nextbits() == extension_start_code) {		
sequence_extension()		
do {		
extension_and_user_data(0)		
do {		
if (nextbits() == group_start_code) {		
group_of_pictures_header()		
extension_and_user_data(1)		
}		
picture_header()		
picture_coding_extension()		
extension_and_user_data(2)		
picture_data()		
} while ((nextbits() == picture_start_code) ||		
(nextbits() == group_start_code))		
if (nextbits() != sequence_end_code) {		
sequence_header()		
sequence_extension()		
}		
} while (nextbits() != sequence_end_code)		
} else {		
/* ISO/IEC 11172-2 */		
}		
sequence_end_code	32	bslbf
}		

6.2.2.1 Sequence header

sequence_header() {	No. of bits	Mnemonic
sequence_header_code	32	bslbf
horizontal_size_value	12	uimsbf
vertical_size_value	12	uimsbf
aspect_ratio_information	4	uimsbf
frame_rate_code	4	uimsbf
bit_rate_value	18	uimsbf
marker_bit	1	bslbf
vbv_buffer_size_value	10	uimsbf
constrained_parameters_flag	1	bslbf
load_intra_quantiser_matrix	1	uimsbf
if (load_intra_quantiser_matrix)		
intra_quantiser_matrix[64]	8*64	uimsbf
load_non_intra_quantiser_matrix	1	uimsbf
if (load_non_intra_quantiser_matrix)		
non_intra_quantiser_matrix[64]	8*64	uimsbf
next_start_code()		
}		

6.2.2.2 Extension and user data

extension_and_user_data(i) {	No. of bits	Mnemonic
while ((nextbits()== extension_start_code) ||		
(nextbits()== user_data_start_code)) {		
if ((i != 1) && (nextbits()== extension_start_code))		
extension_data(i)		
if (nextbits()== user_data_start_code)		
user_data()		
}		
}		

6.2.2.2.1 Extension data

extension_data(i) {	No. of bits	Mnemonic
while (nextbits()== extension_start_code) {		
extension_start_code	32	bslbf
if (i == 0) { /* follows sequence_extension() */		
if (nextbits()== "Sequence Display Extension ID")		
sequence_display_extension()		
else if (nextbits()		
== "Sequence Scalable Extension ID")		
sequence_scalable_extension()		
else		
while (nextbits() != '0000 0000 0000 0000 0000 0001')		
reserved_extension_data_byte	8	uimsbf
}		
/* NOTE – i never takes the value 1 because extension_data()		
never follows a group_of_pictures_header() */		
if (i == 2) { /* follows picture_coding_extension() */		
if (nextbits() == "Quant Matrix Extension ID")		
quant_matrix_extension()		
else if (nextbits() == "Copyright Extension ID")		
copyright_extension()		
else if (nextbits() == "Picture Display Extension ID")		
picture_display_extension()		
else if (nextbits()		
== "Picture Spatial Scalable Extension ID")		
picture_spatial_scalable_extension()		
else if (nextbits()		
== "Picture Temporal Scalable Extension ID")		
picture_temporal_scalable_extension()		
else if (nextbits()		
== "Camera Parameters Extension ID")		
camera_parameters_extension()		
else if (nextbits()		
== "ITU-T Extension ID")		
ITU-T_extension()		
else		
while (nextbits() != '0000 0000 0000 0000 0000 0001')		
reserved_extension_data_byte	8	uimsbf
}		
}		
}		

6.2.2.2.2 User data

user_data() {	No. of bits	Mnemonic
user_data_start_code	32	bslbf
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
user_data	8	uimsbf
}		
next_start_code()		
}		

6.2.2.3 Sequence extension

sequence_extension() {	No. of bits	Mnemonic
extension_start_code	32	bslbf
extension_start_code_identifier	4	uimsbf
profile_and_level_indication	8	uimsbf
progressive_sequence	1	uimsbf
chroma_format	2	uimsbf
horizontal_size_extension	2	uimsbf
vertical_size_extension	2	uimsbf
bit_rate_extension	12	uimsbf
marker_bit	1	bslbf
vbv_buffer_size_extension	8	uimsbf
low_delay	1	uimsbf
frame_rate_extension_n	2	uimsbf
frame_rate_extension_d	5	uimsbf
next_start_code()		
}		

6.2.2.4 Sequence display extension

sequence_display_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
video_format	3	uimsbf
colour_description	1	uimsbf
if (colour_description) {		
colour_primaries	8	uimsbf
transfer_characteristics	8	uimsbf
matrix_coefficients	8	uimsbf
}		
display_horizontal_size	14	uimsbf
marker_bit	1	bslbf
display_vertical_size	14	uimsbf
next_start_code()		
}		

6.2.2.5 Sequence scalable extension

sequence_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
scalable_mode	2	uimsbf
layer_id	4	uimsbf
if (scalable_mode == "spatial scalability") {		
lower_layer_prediction_horizontal_size	14	uimsbf
marker_bit	1	bslbf
lower_layer_prediction_vertical_size	14	uimsbf
horizontal_subsampling_factor_m	5	uimsbf
horizontal_subsampling_factor_n	5	uimsbf
vertical_subsampling_factor_m	5	uimsbf
vertical_subsampling_factor_n	5	uimsbf
}		
if (scalable_mode == "temporal scalability") {		
picture_mux_enable	1	uimsbf
if (picture_mux_enable)		
mux_to_progressive_sequence	1	uimsbf
picture_mux_order	3	uimsbf
picture_mux_factor	3	uimsbf
}		
next_start_code()		
}		

6.2.2.6 Group of pictures header

group_of_pictures_header() {	No. of bits	Mnemonic
group_start_code	32	bslbf
time_code	25	uimsbf
closed_gop	1	uimsbf
broken_link	1	uimsbf
next_start_code()		
}		

6.2.3 Picture header

picture_header() {	No. of bits	Mnemonic
picture_start_code	32	bslbf
temporal_reference	10	uimsbf
picture_coding_type	3	uimsbf
vbv_delay	16	uimsbf
if (picture_coding_type == 2 || picture_coding_type == 3) {		
full_pel_forward_vector	1	bslbf
forward_f_code	3	bslbf
}		
if (picture_coding_type == 3) {		
full_pel_backward_vector	1	bslbf
backward_f_code	3	bslbf
}		
while (nextbits() == '1') {		
extra_bit_picture /* with the value '1' */	1	uimsbf
content_description_data() /* with every 9th bit having the value '1' */	8	uimsbf
}		
extra_bit_picture /* with the value '0' */	1	uimsbf
next_start_code()		
}		

6.2.3.1 Picture coding extension

picture_coding_extension() {	No . of bits	Mnemonic
extension_start_code	32	bslbf
extension_start_code_identifier	4	uimsbf
f_code[0][0] /* forward horizontal */	4	uimsbf
f_code[0][1] /* forward vertical */	4	uimsbf
f_code[1][0] /* backward horizontal */	4	uimsbf
f_code[1][1] /* backward vertical */	4	uimsbf
intra_dc_precision	2	uimsbf
picture_structure	2	uimsbf
top_field_first	1	uimsbf
frame_pred_frame_dct	1	uimsbf
concealment_motion_vectors	1	uimsbf
q_scale_type	1	uimsbf
intra_vlc_format	1	uimsbf
alternate_scan	1	uimsbf
repeat_first_field	1	uimsbf
chroma_420_type	1	uimsbf
progressive_frame	1	uimsbf
composite_display_flag	1	uimsbf
if (composite_display_flag) {		
v_axis	1	uimsbf
field_sequence	3	uimsbf
sub_carrier	1	uimsbf
burst_amplitude	7	uimsbf
sub_carrier_phase	8	uimsbf
}		
next_start_code()		
}		

6.2.3.2 Quant matrix extension

quant_matrix_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
load_intra_quantiser_matrix	1	uimsbf
if (load_intra_quantiser_matrix)		
intra_quantiser_matrix[64]	8 * 64	uimsbf
load_non_intra_quantiser_matrix	1	uimsbf
if (load_non_intra_quantiser_matrix)		
non_intra_quantiser_matrix[64]	8 * 64	uimsbf
load_chroma_intra_quantiser_matrix	1	uimsbf
if (load_chroma_intra_quantiser_matrix)		
chroma_intra_quantiser_matrix[64]	8 * 64	uimsbf
load_chroma_non_intra_quantiser_matrix	1	uimsbf
if (load_chroma_non_intra_quantiser_matrix)		
chroma_non_intra_quantiser_matrix[64]	8 * 64	uimsbf
next_start_code()		
}		

6.2.3.3 Picture display extension

picture_display_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
for (i = 0; i < number_of_frame_centre_offsets; i++) {		
frame_centre_horizontal_offset	16	simsbf
marker_bit	1	bslbf
frame_centre_vertical_offset	16	simsbf
marker_bit	1	bslbf
}		
next_start_code()		
}		

6.2.3.4 Picture temporal scalable extension

picture_temporal_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
reference_select_code	2	uimsbf
forward_temporal_reference	10	uimsbf
marker_bit	1	bslbf
backward_temporal_reference	10	uimsbf
next_start_code()		
}		

6.2.3.5 Picture spatial scalable extension

picture_spatial_scalable_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
lower_layer_temporal_reference	10	uimsbf
marker_bit	1	bslbf
lower_layer_horizontal_offset	15	simsbf
marker_bit	1	bslbf
lower_layer_vertical_offset	15	simsbf
spatial_temporal_weight_code_table_index	2	uimsbf
lower_layer_progressive_frame	1	uimsbf
lower_layer_deinterlaced_field_select	1	uimsbf
next_start_code()		
}		

6.2.3.6 Copyright extension

copyright_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
copyright_flag	1	uimsbf
copyright_identifier	8	uimsbf
original_or_copy	1	uimsbf
reserved	7	bslbf
marker_bit	1	bslbf
copyright_number_1	20	uimsbf
marker_bit	1	bslbf
copyright_number_2	22	uimsbf
marker_bit	1	bslbf
copyright_number_3	22	uimsbf
next_start_code()		
}		

6.2.3.7 Picture data

picture_data() {	No. of bits	Mnemonic
do {		
slice()		
} while (nextbits() == slice_start_code)		
next_start_code()		
}		

6.2.3.7.1 Camera parameters extension

camera_parameters_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
reserved	1	uimsbf
camera_id	7	simsbf
marker_bit	1	bslbf
height_of_image_device	22	uimsbf
marker_bit	1	bslbf
focal_length	22	uimsbf
marker_bit	1	bslbf
f_number	22	uimsbf
marker_bit	1	bslbf
vertical_angle_of_view	22	uimsbf
marker_bit	1	bslbf
camera_position_x_upper	16	simsbf
marker_bit	1	bslbf
camera_position_x_lower	16	
marker_bit	1	bslbf
camera_position_y_upper	16	simsbf
marker_bit	1	bslbf
camera_position_y_lower	16	
marker_bit	1	bslbf
camera_position_z_upper	16	simsbf
marker_bit	1	bslbf
camera_position_z_lower	16	
marker_bit	1	bslbf
camera_direction_x	22	simsbf
marker_bit	1	bslbf
camera_direction_y	22	simsbf
marker_bit	1	bslbf
camera_direction_z	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_x	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_y	22	simsbf
marker_bit	1	bslbf
image_plane_vertical_z	22	simsbf
marker_bit	1	bslbf
reserved	32	bslbf
next_start_code()		
}		

NOTE – The parameters marked 'reserved' in the camera parameters extension shall be equal to zero. Other values are reserved for future use by ITU-T | ISO/IEC.

6.2.3.7.2 ITU-T extension

ITU-T_extension() {	No. of bits	Mnemonic
extension_start_code_identifier	4	uimsbf
while(nextbits() != '0000 0000 0000 0000 0000 0001') {		
ITU-T_data	1	uimsbf
}		
next_start_code()		
}		
NOTE – The construct with the while-statement prevents start code emulation.		

6.2.3.7.3 Content description data

content_description_data() {	No. of bits	Mnemonic
data_type_upper	8	uimsbf
marker_bit	1	bslbf
data_type_lower	8	
marker_bit	1	bslbf
data_length	8	uimsbf
if (data_type == "Padding Bytes")		
padding_bytes()		
else if (data_type == "Capture Timecode")		
capture_timecode()		
else if (data_type == "Additional Pan-Scan Parameters")		
additional_pan_scan_parameters()		
else if (data_type == "Active Region Window")		
active_region_window()		
else if (data_type == "Coded Picture Length")		
coded_picture_length()		
else		
for (i = 0; i < data_length; i ++) {		
marker_bit	1	bslbf
reserved_content_description_data	8	uimsbf
}		
}		

6.2.3.7.3.1 Padding bytes

padding_bytes() {	No. of bits	Mnemonic
for (i = 0; i < data_length; i ++) {		
marker_bit	1	bslbf
padding_byte	8	bslbf
}		
}		

6.2.3.7.3.2 Capture timecode

capture_timecode() {	No. of bits	Mnemonic
marker_bit	1	bslbf
timecode_type	2	uimsbf
counting_type	3	uimsbf
reserved_bit	1	uimsbf
reserved_bit	1	uimsbf
reserved_bit	1	uimsbf
if (counting_type != 0) {		
marker_bit	1	bslbf
nframes_conversion_code	1	uimsbf
clock_divisor	7	uimsbf
marker_bit	1	bslbf
nframes_multiplier_upper	8	uimsbf
marker_bit	1	bslbf
nframes_multiplier_lower	8	
}		
frame_or_field_capture_timestamp()		
if (timecode_type == '11')		
frame_or_field_capture_timestamp()		
}		

6.2.3.7.3.2.1 Frame or field capture timestamp

frame_or_field_capture_timestamp() {	No. of bits	Mnemonic
if (counting_type != 0) {		
marker_bit	1	bslbf
nframes	8	uimsbf
}		
marker_bit	1	bslbf
time_discontinuity	1	uimsbf
prior_count_dropped	1	uimsbf
time_offset_part_a	6	simsbf
marker_bit	1	bslbf
time_offset_part_b	8	
marker_bit	1	bslbf
time_offset_part_c	8	
marker_bit	1	bslbf
time_offset_part_d	8	
marker_bit	1	bslbf
units_of_seconds	4	uimsbf
tens_of_seconds	4	uimsbf
marker_bit	1	bslbf
units_of_minutes	4	uimsbf
tens_of_minutes	4	uimsbf
marker_bit	1	bslbf
units_of_hours	4	uimsbf
tens_of_hours	4	uimsbf
}		

6.2.3.7.3.3 Additional pan-scan parameters

additional_pan_scan_parameters() {	No. of bits	Mnemonic
marker_bit	1	bslbf
aspect_ratio_information	4	uimsbf
reserved_bit	1	bslbf
reserved_bit	1	bslbf
reserved_bit	1	bslbf
display_size_present	1	bslbf
if (display_size_present == '1') {		
marker_bit	1	bslbf
reserved_bit	1	bslbf
reserved_bit	1	bslbf
display_horizontal_size_upper	6	uimsbf
marker_bit	1	bslbf
display_horizontal_size_lower	8	
marker_bit	1	bslbf
reserved_bit	1	bslbf
reserved_bit	1	bslbf
display_vertical_size_upper	6	uimsbf
marker_bit	1	bslbf
display_vertical_size_lower	8	
}		
for (i = 0; i < number_of_frame_centre_offsets; i ++) {		
marker_bit	1	bslbf
frame_centre_horizontal_offset_upper	8	simsbf
marker_bit	1	bslbf
frame_centre_horizontal_offset_lower	8	
marker_bit	1	bslbf
frame_centre_vertical_offset_upper	8	simsbf
marker_bit	1	bslbf
frame_centre_vertical_offset_lower	8	
}		
}		

6.2.3.7.3.4 Active region window

active_region_window() {	No. of bits	Mnemonic
marker_bit	1	bslbf
top_left_x_upper	8	uimsbf
marker_bit	1	bslbf
top_left_x_lower	8	
marker_bit	1	bslbf
top_left_y_upper	8	uimsbf
marker_bit	1	bslbf
top_left_y_lower	8	
marker_bit	1	bslbf
active_horizontal_size_upper	8	uimsbf
marker_bit	1	bslbf
active_horizontal_size_lower	8	
marker_bit	1	bslbf
active_vertical_size_upper	8	uimsbf
marker_bit	1	bslbf
active_vertical_size_lower	8	
}		

6.2.3.7.3.5 Coded picture length

coded_picture_length() {	No. of bits	Mnemonic
marker_bit	1	bslbf
picture_byte_count_part_a	8	uimsbf
marker_bit	1	bslbf
picture_byte_count_part_b	8	
marker_bit	1	bslbf
picture_byte_count_part_c	8	
marker_bit	1	bslbf
picture_byte_count_part_d	8	
}		

6.2.4 Slice

slice() {	No. of bits	Mnemonic
slice_start_code	32	bslbf
if (vertical_size > 2800)		
slice_vertical_position_extension	3	uimsbf
if (<sequence_scalable_extension() is present in the bitstream>) {		
if (scalable_mode == 'data partitioning')		
priority_breakpoint	7	uimsbf
}		
quantiser_scale_code	5	uimsbf
if (nextbits() == '1') {		
slice_extension_flag	1	bslbf
intra_slice	1	uimsbf
slice_picture_id_enable	1	uimsbf
slice_picture_id	6	uimbsf
while (nextbits() == '1') {		
extra_bit_slice /* with the value '1' */	1	uimsbf
extra_information_slice	8	uimsbf
}		
}		
extra_bit_slice /* with the value '0' */	1	uimsbf
do {		
macroblock()		
} while (nextbits() != '000 0000 0000 0000 0000 0000')		
next_start_code()		
}		

6.2.5 Macroblock

macroblock() {	No. of bits	Mnemonic
while (nextbits() == '0000 0001 000')		
macroblock_escape	11	bslbf
macroblock_address_increment	1-11	vlclbf
macroblock_modes()		
if (macroblock_quant)		
quantiser_scale_code	5	uimsbf
if (macroblock_motion_forward ||		
(macroblock_intra && concealment_motion_vectors))		
motion_vectors(0)		
if (macroblock_motion_backward)		
motion_vectors(1)		
if (macroblock_intra && concealment_motion_vectors)		
marker_bit	1	bslbf
if (macroblock_pattern)		
coded_block_pattern()		
for (i = 0; i < block_count; i + +) {		
block(i)		
}		
}		

6.2.5.1 Macroblock modes

macroblock_modes() {	No. of bits	Mnemonic
macroblock_type	1-9	vlclbf
if ((spatial_temporal_weight_code_flag == 1) &&		
(spatial_temporal_weight_code_table_index != '00')) {		
spatial_temporal_weight_code	2	uimsbf
}		
if (macroblock_motion_forward ||		
macroblock_motion_backward) {		
if (picture_structure == 'frame') {		
if (frame_pred_frame_dct == 0)		
frame_motion_type	2	uimsbf
} else {		
field_motion_type	2	uimsbf
}		
}		
if ((picture_structure == "Frame picture") &&		
(frame_pred_frame_dct == 0) &&		
(macroblock_intra || macoblock_pattern)){		
dct_type	1	uimsbf
}		
}		

6.2.5.2 Motion vectors

motion_vectors (s) {	No. of bits	Mnemonic
if (motion_vector_count == 1) {		
if ((mv_format == field) && (dmv != 1))		
motion_vertical_field_select[0][s]	1	uimsbf
motion_vector(0, s)		
} else {		
motion_vertical_field_select[0][s]	1	uimsbf
motion_vector(0, s)		
motion_vertical_field_select[1][s]	1	uimsbf
motion_vector(1, s)		
}		
}		

6.2.5.2.1 Motion vector

motion_vector (r, s) {	No. of bits	Mnemonic
motion_code[r][s][0]	1-11	vlclbf
if ((f_code[s][0] != 1) && (motion_code[r][s][0] != 0))		
motion_residual[r][s][0]	1-8	uimsbf
if (dmv == 1)		
dmvector[0]	1-2	vlclbf
motion_code[r][s][1]	1-11	vlclbf
if ((f_code[s][1] != 1) && (motion_code[r][s][1] != 0))		
motion_residual[r][s][1]	1-8	uimsbf
if (dmv == 1)		
dmvector[1]	1-2	vlclbf
}		

6.2.5.3 Coded block pattern

coded_block_pattern () {	No. of bits	Mnemonic
coded_block_pattern_420	3-9	vlclbf
if (chroma_format == 4:2:2)		
coded_block_pattern_1	2	uimsbf
if (chroma_format == 4:4:4)		
coded_block_pattern_2	6	uimsbf
}		

6.2.6 Block

The detailed syntax for the terms "First DCT coefficient", "Subsequent DCT coefficient" and "End of Block" is fully described in 7.2.

This subclause does not adequately document the block layer syntax when data partitioning is used. See 7.10.

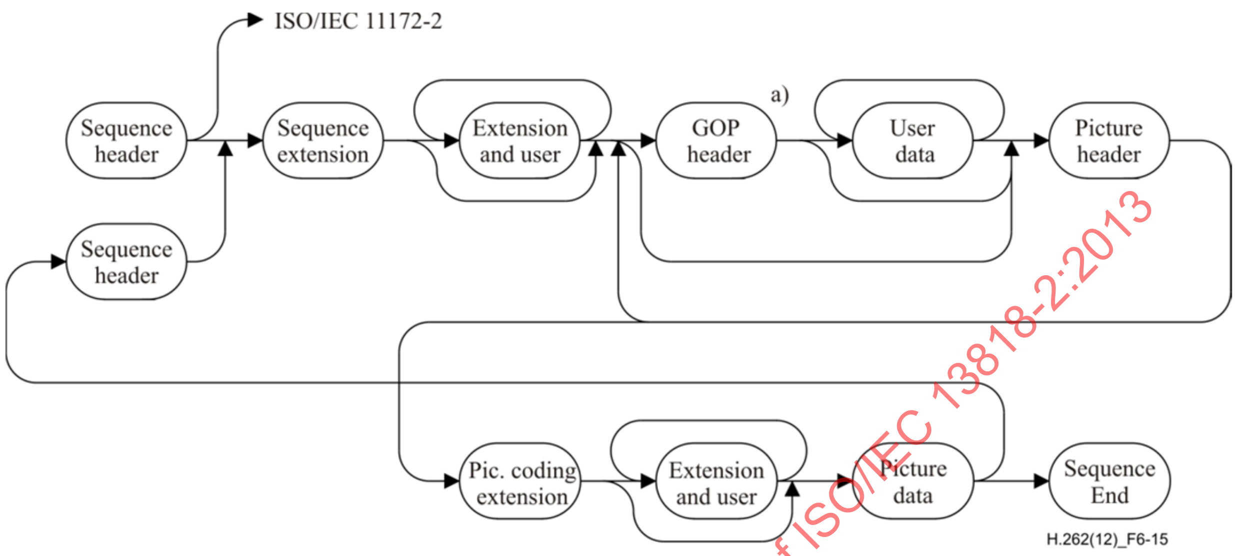
block(i) {	No. of bits	Mnemonic
if (pattern_code[i]) {		
if (macroblock_intra) {		
if (i < 4) {		
dct_dc_size_luminance	2-9	vlclbf
if(dct_dc_size_luminance != 0)		
dct_dc_differential	1-11	uimsbf
} else {		
dct_dc_size_chrominance	2-10	vlclbf
if(dct_dc_size_chrominance != 0)		
dct_dc_differential	1-11	uimsbf
}		
} else {		
First DCT coefficient	2-24	vlclbf
}		
while (nextbits() != End of block)		
Subsequent DCT coefficients	3-24	vlclbf
End of block	2 or 4	vlclbf
}		
}		

6.3 Video bitstream semantics

6.3.1 Semantic rules for higher syntactic structures

This subclause details the rules that govern the way in which the higher level syntactic elements may be combined together to produce a legal bitstream. Subsequent clauses detail the semantic meaning of all fields in the video bitstream.

Figure 6-15 illustrates the high level structure of the video bitstream.



a) After a group of pictures (GOP) header, the first picture shall be an I-picture

Figure 6-15 – High level bitstream organization

The following semantic rules apply:

- If the first sequence_header() of the sequence is not followed by sequence_extension(), then the stream shall conform to ISO/IEC 11172-2 and is not documented within this Specification.
- If the first sequence_header() of a sequence is followed by a sequence_extension(), then all subsequent occurrences of sequence_header() shall also be immediately followed by a sequence_extension().
- sequence_extension() shall only occur immediately following a sequence_header().
- Following a sequence_header() there shall be at least one coded picture before a repeat sequence_header() or a sequence_end_code. This implies that sequence_extension() shall not immediately precede a sequence_end_code.
- If sequence_extension() occurs in the bitstream, then each picture_header() shall be followed immediately by a picture_coding_extension().
- sequence_end_code shall be positioned at the end of the bitstream such that, after decoding and frame re-ordering, there shall be no missing frames.
- picture_coding_extension() shall only occur immediately following a picture_header().
- The first coded frame following a group_of_pictures_header() shall be a coded I-frame.

A number of different extensions are defined in addition to sequence_extension() and picture_coding_extension(). The set of allowed extensions is different at each different point in the syntax where extensions are allowed. Table 6-2 defines a four bit extension_start_code_identifier for each extension.

Table 6-2 – extension_start_code_identifier codes

extension_start_code_identifier	Name
0000	Reserved
0001	Sequence Extension ID
0010	Sequence Display Extension ID
0011	Quant Matrix Extension ID
0100	Copyright Extension ID
0101	Sequence Scalable Extension ID
0110	Reserved
0111	Picture Display Extension ID
1000	Picture Coding Extension ID
1001	Picture Spatial Scalable Extension ID
1010	Picture Temporal Scalable Extension ID
1011	Camera Parameters Extension ID
1100	ITU-T extension ID
1101	Reserved
...	...
1111	Reserved

At each point where extensions are allowed in the bitstream any number of the extensions from the defined allowable set may be included. However, each type of extension shall not occur more than once.

In the case that a decoder encounters an extension with an extension identification that is described as "reserved" in this Specification, the decoder shall discard all subsequent data until the next start code. This requirement allows future definition of compatible extensions to this Specification.

6.3.2 Video sequence

sequence_end_code – The sequence_end_code is the bit string '000001B7' in hexadecimal. It terminates a video sequence.

6.3.3 Sequence header

sequence_header_code – The sequence_header_code is the bit string '000001B3' in hexadecimal. It identifies the beginning of a sequence header.

horizontal_size_value – This word forms the 12 least significant bits of horizontal_size.

vertical_size_value – This word forms the 12 least significant bits of vertical_size.

horizontal_size – The horizontal_size is a 14-bit unsigned integer, the 12 least significant bits are defined in horizontal_size_value, the 2 most significant bits are defined in horizontal_size_extension. The horizontal_size is the width of the displayable part of the luminance component of pictures in samples. The width of the encoded luminance component of pictures in macroblocks, mb_width, is (horizontal_size + 15)/16. The displayable part is left-aligned in the encoded pictures.

In order to avoid start code emulation horizontal_size_value shall not be zero. This precludes values of horizontal_size that are multiples of 4096.

vertical_size – The vertical_size is a 14-bit unsigned integer, the 12 least significant bits are defined in vertical_size_value, the 2 most significant bits are defined in vertical_size_extension. The vertical_size is the height of the displayable part of the luminance component of the frame in lines.

In the case that progressive_sequence is '1' the height of the encoded luminance component of frames in macroblocks, mb_height, is (vertical_size + 15)/16.

In the case that progressive_sequence is '0' the height of the encoded luminance component of frame pictures in macroblocks, mb_height, is 2*((vertical_size + 31)/32). The height of the encoded luminance component of field pictures in macroblocks, mb_height, is ((vertical_size + 31)/32).

The displayable part is top-aligned in the encoded pictures.

In order to avoid start code emulation vertical_size_value shall not be zero. This precludes values of vertical_size that are multiples of 4096.

aspect_ratio_information – This is a four-bit integer defined in Table 6-3.

Table 6-3 – aspect_ratio_information

aspect_ratio_information	Sample Aspect Ratio	DAR
0000	Forbidden	Forbidden
0001	1.0 (Square Sample)	–
0010	–	3 ÷ 4
0011	–	9 ÷ 16
0100	–	1 ÷ 2.21
0101	–	Reserved
…		…
1111	–	Reserved

aspect_ratio_information either specifies that the "Sample Aspect Ratio" (SAR) of the reconstructed frame is 1.0 (square samples) or alternatively it gives the "Display Aspect Ratio" (DAR).

- If sequence_display_extension() is not present, then it is intended that the entire reconstructed frame is intended to be mapped to the entire active region of the display. The sample aspect ratio may be calculated as follows:

$$SAR = DAR \times \frac{horizontal\_size}{vertical\_size}$$

NOTE 1 – In this case horizontal_size and vertical_size are constrained by the SAR of the source and the DAR selected.

- If sequence_display_extension() is present then the sample aspect ratio may be calculated as follows:

$$SAR = DAR \times \frac{display\_horizontal\_size}{display\_vertical\_size}$$

frame_rate_code – This is a four-bit integer used to define frame_rate_value as shown in Table 6-4. frame_rate may be derived from frame_rate_value, frame_rate_extension_n and frame_rate_extension_d as follows:

$$frame\_rate = frame\_rate\_value * (frame\_rate\_extension\_n + 1) \div (frame\_rate\_extension\_d + 1)$$

When an entry for the frame rate exists directly in Table 6-4, frame_rate_extension_n and frame_rate_extension_d shall be zero. (frame_rate_extension_n + 1) and (frame_rate_extension_d + 1) shall not have a common divisor greater than one.

Table 6-4 – frame_rate_value

frame_rate_code	frame_rate_value
0000	Forbidden
0001	24 000 ÷ 1001 (23.976…)
0010	24
0011	25
0100	30 000 ÷ 1001 (29.97…)
0101	30
0110	50
0111	60 000 ÷ 1001 (59.94…)
1000	60
1001	Reserved
…	…
1111	Reserved

If progressive_sequence is '1' the period between two successive frames at the output of the decoding process is the reciprocal of the frame_rate. See Figure 7-18.

If progressive_sequence is '0' the period between two successive fields at the output of the decoding process is half of the reciprocal of the frame_rate. See Figure 7-20.

The frame_rate signalled in the enhancement layer of temporal scalability is the combined frame rate after the temporal re-multiplex operation if picture_mux_enable in the sequence_scalable_extension() is set to '1'.

bit_rate_value – The lower 18 bits of bit_rate.

bit_rate – This is a 30-bit integer. The lower 18 bits of the integer are in bit_rate_value and the upper 12 bits are in bit_rate_extension. bit_rate is measured in units of 400 bits/second, rounded upwards. The value zero is forbidden.

The bit rate specified bounds the maximum rate of operation of the VBV as defined in C.3.

The VBV operates in one of two modes depending on the coded values in vbv_delay. In all cases (both constant and variable bit rate operation) the bit rate specified shall be the upper bound of the rate at which the coded data is supplied to the input of the VBV.

NOTE 2 – Since constant bit rate operation is simply a special case of variable bit rate operation there is no requirement that the value of bit_rate is the actual bit rate at which the data is supplied. However it is recommended in the case of constant bit rate operation that bit_rate should represent the actual bit rate.

marker_bit – This is one bit that shall be set to '1'. This bit prevents emulation of start codes.

vbv_buffer_size_value – the lower 10 bits of vbv_buffer_size.

vbv_buffer_size – vbv_buffer_size is an 18-bit integer. The lower 10 bits of the integer are in vbv_buffer_size_value and the upper 8 bits are in vbv_buffer_size_extension. The integer defines the size of the VBV (Video Buffering Verifier, see Annex C) buffer needed to decode the sequence. It is defined as:

$$B = 16 * 1024 * vbv\_buffer\_size$$

where B is the minimum VBV buffer size in bits required to decode the sequence (see Annex C).

constrained_parameters_flag – This flag (used in ISO/IEC 11172-2) has no meaning in this Specification and shall have the value '0'.

load_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

load_non_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

non_intra_quantiser_matrix – See 6.3.11 "Quant matrix extension".

6.3.4 Extension and user data

extension_start_code – The extension_start_code is the bit string '000001B5' in hexadecimal. It identifies the beginning of extensions beyond ISO/IEC 11172-2.

6.3.4.1 User data

user_data_start_code – The user_data_start_code is the bit string '000001B2' in hexadecimal. It identifies the beginning of user data. The user data continues until receipt of another start code.

user_data – This is an 8 bit integer, an arbitrary number of which may follow one another. Except as specified in Annex D, the values and semantics of the user data sent as user_data syntax elements are defined by users for their specific applications. In the series of consecutive user_data bytes there shall not be a string of 23 or more consecutive zero bits. Except as specified in Annex D, the user data shall not begin with the bit string '4a503344' in hexadecimal.

6.3.5 Sequence extension

extension_start_code_identifier – This is a 4-bit integer which identifies the extension. See Table 6-2.

profile_and_level_indication – This is an 8-bit integer used to signal the profile and level identification. The meaning of the bits is given in clause 8.

NOTE – In a scalable hierarchy the bitstreams of each layer may set profile_and_level_indication to a different value as specified in clause 8.

progressive_sequence – When set to '1' the coded video sequence contains only progressive frame pictures. When progressive_sequence is set to '0' the coded video sequence may contain both frame pictures and field pictures, and frame picture may be progressive or interlaced frames.

chroma_format – This is a two-bit integer indicating the chrominance format as defined in Table 6-5.

horizontal_size_extension – This 2-bit integer is the 2 most significant bits from horizontal_size.

vertical_size_extension – This 2-bit integer is the 2 most significant bits from vertical_size.

bit_rate_extension – This 12-bit integer is the 12 most significant bits from bit_rate.

vbv_buffer_size_extension – This 8-bit integer is the 8 most significant bits from vbv_buffer_size.

Table 6-5 – Meaning of chroma_format

chroma_format	Meaning
00	Reserved
01	4:2:0
10	4:2:2
11	4:4:4

low_delay – This flag, when set to '1', indicates that the sequence does not contain any B-pictures, that the frame re-ordering delay is not present in the VBV description and that the bitstream may contain "big pictures", i.e. that C.7 of the VBV may apply.

When set to '0', it indicates that the sequence may contain B-pictures, that the frame re-ordering delay is present in the VBV description and that bitstream shall not contain big pictures, i.e. C.7 of the VBV does not apply.

This flag is not used during the decoding process and therefore can be ignored by decoders, but it is necessary to define and verify the compliance of low-delay bitstreams.

frame_rate_extension_n – This is a 2-bit integer used to determine the frame_rate. See frame_rate_code.

frame_rate_extension_d – This is a 5-bit integer used to determine the frame_rate. See frame_rate_code.

6.3.6 Sequence display extension

This Specification does not define the display process. The information in this extension does not affect the decoding process and may be ignored by decoders that conform to this Specification.

video_format – This is a three bit integer indicating the representation of the pictures before being coded in accordance with this Specification. Its meaning is defined in Table 6-6. If the sequence_display_extension() is not present in the bitstream, then the video format may be assumed to be "Unspecified video format".

Table 6-6 – Meaning of video_format

video_format	Meaning
000	Component
001	PAL
010	NTSC
011	SECAM
100	MAC
101	Unspecified video format
110	Reserved
111	Reserved

colour_description – A flag which if set to '1' indicates the presence of colour_primaries, transfer_characteristics and matrix_coefficients in the bitstream.

colour_primaries – This 8-bit integer describes the chromaticity coordinates of the source primaries, and is defined in Table 6-7.

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero, the chromaticity is assumed to be implicitly defined by the application.

transfer_characteristics – This 8-bit integer describes the opto-electronic transfer characteristic of the source picture, and is defined in Table 6-8.

Table 6-7 – Colour primaries

Value	Primaries			Informative remarks*
0	Forbidden			
1	primary	x	y	Rec. ITU-R BT.709 [2] Rec. ITU-R BT.1361 [4], conventional colour gamut system or extended colour gamut system IEC 61966-2-4 [9] Annex B of SMPTE RP 177 [17]
	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			For future use by ITU-T | ISO/IEC
4	primary	x	y	Rec. ITU-R BT.470, System M (historical) NTSC-1953 [16], Recommendation for transmission standards for colour television US 47 CFR 73.682 (a) (20) [20]
	green	0.21	0.71	
	blue	0.14	0.08	
	red	0.67	0.33	
	white C	0.310	0.316	
5	primary	x	y	Rec. ITU-R BT.470, System B, G (historical) Rec. ITU-R BT.601 (see Clause 2 for title), 625 Rec. ITU-R BT.1358 [3], 625 Rec. ITU-R BT.1700 [5], 625 PAL or 625 SECAM
	green	0.29	0.60	
	blue	0.15	0.06	
	red	0.64	0.33	
	white D65	0.3127	0.3290	
6	primary	x	y	(functionally the same as the value 7) Rec. ITU-R BT.601 (see Clause 2 for title), 525 Rec. ITU-R BT.1358 [3], 525 Rec. ITU-R BT.1700 [5], NTSC SMPTE ST 170 [18]
	green	0.310	0.595	
	blue	0.155	0.070	
	red	0.630	0.340	
	white D65	0.3127	0.3290	
7	primary	x	y	(functionally the same as the value 6) SMPTE ST 240 [19]
	green	0.310	0.595	
	blue	0.155	0.070	
	red	0.630	0.340	
	white D65	0.3127	0.3290	
8-255	Reserved			For future use by ITU-T | ISO/IEC

* [x] indicates item 'x' in the Bibliography of this Recommendation | International Standard

Table 6-8 – Transfer characteristics

Value	Transfer characteristic	Informative remarks*
0	Forbidden	
1	$V = 1.099\ L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c \geq 0$	(functionally the same as the value 6) Rec. ITU-R BT.709 [2] Rec. ITU-R BT.1361 [4], conventional colour gamut system
2	Unspecified	Image characteristics are unknown or are determined by the application.
3	Reserved	For future use by ITU-T | ISO/IEC
4	Assumed display gamma 2.2	Rec. ITU-R BT.470, System M (historical) NTSC-1953 [16], Recommendation for transmission standards for colour television US 47 CFR 73.682 (a) (20) [20]
5	Assumed display gamma 2.8	Rec. ITU-R BT.470, System B, G (historical) Rec. ITU-R BT.1700 [5], 625 PAL or 625 SECAM
6	$V = 1.099\ L_c^{0.45} - 0.099$ for $1 \geq L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c \geq 0$	(functionally the same as the value 1) Rec. ITU-R BT.601 (see Clause 2 for title), 525 or 625 Rec. ITU-R BT.1700 [5], NTSC Rec. ITU-R BT.1358 [3], 525 or 625 SMPTE ST 170 [18]
7	$V = 1.1115\ L_c^{0.45} - 0.1115$ for $L_c \geq 0.0228$ $V = 4.0\ L_c$ for $0.0228 > L_c$	SMPTE ST 240 [19]
8	$V = L_c$	Linear transfer characteristics
9	$V = 1.0 - \mathrm{Log}_{10}(L_c) \div 2$ 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	$V = 1.0 - \mathrm{Log}_{10}(L_c) \div 2.5$ 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	$V = 1.099\ L_c^{0.45} - 0.099$ for $L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c > -0.018$ $V = -(1.099\ (-L_c)^{0.45} - 0.099)$ for $-0.018 \geq L_c$	IEC 61966-2-4 [9]
12	$V = 1.099\ L_c^{0.45} - 0.099$ for $1.33 > L_c \geq 0.018$ $V = 4.500\ L_c$ for $0.018 > L_c \geq -0.0045$ $V = -(1.099\ (-4 * L_c)^{0.45} - 0.099) \div 4$ for $-0.0045 > L_c \geq -0.25$	Rec. ITU-R BT.1361 [4], extended colour gamut system
13-255	Reserved	For future use by ITU-T | ISO/IEC

* [x] indicates item 'x' in the Bibliography of this Recommendation | International Standard

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero, the transfer characteristics are assumed to be implicitly defined by the application.

matrix_coefficients – This 8-bit integer describes the matrix coefficients used in deriving luminance and chrominance signals from the green, blue, and red primaries, and is defined in Table 6-9.

Table 6-9 – Matrix coefficients

Value	Matrix	Informative remarks*
0	Forbidden	
1	$E'_Y = 0.7152\,E'_G + 0.0722\,E'_B + 0.2126\,E'_R$ $E'_{PB} = -\,0.3854\,E'_G + 0.5000\,E'_B - 0.1146\,E'_R$ $E'_{PR} = -\,0.4542\,E'_G - 0.0458\,E'_B + 0.5000\,E'_R$	Rec. ITU-R BT.709 [2] Rec. ITU-R BT.1361 [4], conventional colour gamut system and extended colour gamut system IEC 61966-2-4 [9], $xvYCC_{709}$ Annex B of SMPTE RP 177 [17]
2	Unspecified	Image characteristics are unknown or are determined by the application
3	Reserved	For future use by ITU-T | ISO/IEC
4	$E'_Y = 0.59\,E'_G + 0.11\,E'_B + 0.30\,E'_R$ $E'_{PB} = -\,0.331\,E'_G + 0.500\,E'_B - 0.169\,E'_R$ $E'_{PR} = -\,0.421\,E'_G - 0.079\,E'_B + 0.500\,E'_R$	NTSC-1953 [16], Recommendation for transmission standards for colour television US 47 CFR 73.682 (a) (20) [20]
5	$E'_Y = 0.5870\,E'_G + 0.1140\,E'_B + 0.2990\,E'_R$ $E'_{PB} = -\,0.3313\,E'_G + 0.5000\,E'_B - 0.1687\,E'_R$ $E'_{PR} = -\,0.4187\,E'_G - 0.0813\,E'_B + 0.5000\,E'_R$	(functionally the same as the value 6) Rec. ITU-R BT.470, System B, G (historical) Rec. ITU-R BT.601 (see Clause 2 for title), 625 Rec. ITU-R BT.1358 [3], 625 Rec. ITU-R BT.1700 [5], 625 PAL or 625 SECAM IEC 61966-2-4 [9], $xvYCC_{601}$
6	$E'_Y = 0.5870\,E'_G + 0.1140\,E'_B + 0.2990\,E'_R$ $E'_{PB} = -\,0.3313\,E'_G + 0.5000\,E'_B - 0.1687\,E'_R$ $E'_{PR} = -\,0.4187\,E'_G - 0.0813\,E'_B + 0.5000\,E'_R$	(functionally the same as the value 5) Rec. ITU-R BT.601 (see Clause 2 for title), 525 Rec. ITU-R BT.1358 525 Rec. ITU-R BT.1700 NTSC SMPTE ST 170 [18] IEC 61966-2-4 [9], $xvYCC_{601}$
7	$E'_Y = 0.701\,E'_G + 0.087\,E'_B + 0.212\,E'_R$ $E'_{PB} = -\,0.384\,E'_G + 0.500\,E'_B - 0.116\,E'_R$ $E'_{PR} = -\,0.445\,E'_G - 0.055\,E'_B + 0.500\,E'_R$	SMPTE ST 240 [19]
8	YCgCo	Defined as specified below
9-255	Reserved	For future use by ITU-T | ISO/IEC
* [x] indicates item 'x' in the Bibliography of this Recommendation | International Standard		

In Table 6-9:

– When transfer_characteristics is not equal to 11 or 12, E'_R, E'_G and E'_B are analogue with values between 0 and 1;

– When transfer_characteristics is equal to 11 (IEC 61966-2-4 [9]) or 12 (Rec. ITU-R BT.1361 [4], extended colour gamut system), E'_R, E'_G and E'_B are analogue with a larger range that is not specified in this Recommendation | International Standard;

– Nominal black is considered to have the property $E'_R = 0$, $E'_G = 0$ and $E'_B = 0$;

– Nominal white is considered to have the property $E'_R = 1$, $E'_G = 1$ and $E'_B = 1$;

– If matrix_coefficients is not equal to 8, the following applies:

  – E'_Y is analogue with the value 0 associated with nominal black and the value 1 associated with nominal white;

  – E'_{PB} and E'_{PR} are analogue with the value 0 associated with both nominal black and nominal white;

  – When transfer_characteristics is not equal to 11 or 12, E'_Y has values between 0 and 1;

  – When transfer_characteristics is not equal to 11 or 12, E'_{PB} and E'_{PR} have values between –0.5 and 0.5;

  – When transfer_characteristics is equal to 11 (IEC 61966-2-4 [9]), or 12 (Rec. ITU-R BT.1361 [4], extended colour gamut system), E'_Y, E'_{PB} and E'_{PR} are analogue with a larger range that is not specified in this Recommendation | International Standard;

– Y, Cb and Cr are related to E'_Y, E'_{PB} and E'_{PR} by the following formulae:

$$Y = \max[\ 0, \min[\ 255, \mathrm{Round}(\ (\ 219 * E'_Y\ )\ ) + 16\ ]\ ]$$
$$Cb = \max[\ 0, \min[\ 255, \mathrm{Round}(\ (\ 224 * E'_{PB}\ )\ ) + 128]\ ]$$
$$Cr = \max[\ 0, \min[\ 255, \mathrm{Round}(\ (\ 224 * E'_{PR}\ )\ ) + 128]\ ]$$

– Otherwise (matrix_coefficients is equal to 8 (YCgCo)), the following applies:

$$R = 219 * E'_R + 16$$
$$G = 219 * E'_G + 16$$
$$B = 219 * E'_B + 16$$

$$Y = \max[\ 0, \min[\ 255, \mathrm{Round}(\ 0.5 * G + 0.25 * (\ R + B\ )\ )\ \ ]\ ]$$
$$Cb = \max[\ 0, \min[\ 255, \mathrm{Round}(\ 0.5 * G - 0.25 * (\ R + B\ )\ ) + 128\ ]\ ]$$
$$Cr = \max[\ 0, \min[\ 255, \mathrm{Round}(\ 0.5 * (R - B\ )\ ) + 128\ ]\ ]$$

NOTE 1 – For purposes of the YCgCo nomenclature used in Table 6-9, Cb and Cr of the above equations may be referred to as Cg and Co, respectively. The inverse conversion for the above three equations should be computed as:

$$t = Y - (\ Cb - 128\ )$$
$$G = Y + (\ Cb - 128\ )$$
$$B = t - (\ Cr - 128\ )$$
$$R = t + (\ Cr - 128\ )$$

NOTE 2 – The decoding process given by this Specification limits output sample values for Y, Cr and Cb to the range [0:255]. Thus, sample values outside the range implied by the above equations may occasionally occur at the output of the decoding process. In particular the sample values 0 and 255 may occur.

In the case that sequence_display_extension() is not present in the bitstream or colour_description is zero the matrix coefficients are assumed to be implicitly defined by the application.

NOTE 3 – In applications which may have signals with more than one set of colour primaries, transfer characteristics, and/or matrix coefficients, it is recommended to transmit a sequence display extension with colour_description set to one, and to specify the appropriate values for the colorimetry parameters.

display_horizontal_size – See display_vertical_size.

display_vertical_size – display_horizontal_size and display_vertical_size together define a rectangle which may be considered as the "intended display's" active region. If this rectangle is smaller than the encoded frame size, then the display process may be expected to display only a portion of the encoded frame. Conversely if the display rectangle is larger than the encoded frame size, then the display process may be expected to display the reconstructed frames on a portion of the display device rather than on the whole display device.

display_horizontal_size shall be in the same units as horizontal_size (samples of the encoded frames).

display_vertical_size shall be in the same units as vertical_size (lines of the encoded frames).

display_horizontal_size and display_vertical_size do not affect the decoding process but may be used by the display process that is not standardized in this Specification.

6.3.7 Sequence scalable extension

It is a syntactic restriction that if a sequence_scalable_extension() is present in the bitstream following a given sequence_extension(), then sequence_scalable_extension() shall follow every other occurrence of sequence_extension(). Thus a bitstream is either scalable or it is not scalable. It is not possible to mix scalable and non-scalable coding within a sequence.

scalable_mode – The scalable_mode indicates the type of scalability used in the video sequence. If no sequence_scalable_extension() is present in the bitstream, then no scalability is used for that sequence. scalable_mode also indicates the macroblock_type tables to be used. However, in the case of spatial scalability if no picture_spatial_scalable_extension() is present for a given picture, then that picture shall be decoded in a non-scalable manner (i.e. as if sequence_scalable_extension() had not been present).

Table 6-10 – Definition of scalable_mode

scalable_mode	Meaning	**picture_spatial_scalable-_extension()**	**macroblock_type tables**
sequence_scalable_extension() not present			B-2, B-3 and B-4
00	Data partitioning		B-2, B-3 and B-4
01	Spatial scalability	Present	B-5, B-6 and B-7
		Not present	B-2, B-3 and B-4
10	SNR scalability		B-8
11	Temporal scalability		B-2, B-3 and B-4

layer_id – This is an integer which identifies the layers in a scalable hierarchy. The base layer always has layer_id = 0. However, the base layer of a scalable hierarchy does not carry a sequence_scalable_extension() and hence layer_id, except in the case of data partitioning. Each successive layer has a layer_id which is one greater than the layer for which it is an enhancement.

In the case of data partitioning layer_id shall be zero for partition zero and layer_id shall be one for partition one.

lower_layer_prediction_horizontal_size – This is a 14-bit integer indicating the horizontal size of the lower layer frame which is used for prediction. This shall contain the value contained in horizontal_size (horizontal_size_value and horizontal_size_extension) in the lower layer bitstream.

lower_layer_prediction_vertical_size – This is a 14-bit integer indicating the vertical size of the lower layer frame which is used for prediction. This shall contain the value contained in vertical_size (vertical_size_value and vertical_size_extension) in the lower layer bitstream.

horizontal_subsampling_factor_m – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

horizontal_subsampling_factor_n – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

vertical_subsampling_factor_m – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

vertical_subsampling_factor_n – This affects the spatial scalable upsampling process, as defined in 7.7.2. The value zero is forbidden.

picture_mux_enable – If set to 1, picture_mux_order and picture_mux_factor are used for re-multiplexing prior to display.

mux_to_progressive_sequence – This flag when set to '1' indicates that the decoded pictures corresponding to the two layers shall be temporally multiplexed to generate a progressive sequence for display. When the temporal multiplexing is intended to generate an interlaced sequence this flag shall be '0'.

picture_mux_order – It denotes number of enhancement layer pictures prior to the first base layer picture. It thus assists re-multiplexing of pictures prior to display as it contains information for inverting the demultiplexing performed at the encoder.

picture_mux_factor – It denotes number of enhancement layer pictures between consecutive base layer pictures to allow correct re-multiplexing of base and enhancement layers for display. It also assists in re-multiplexing of pictures prior to display as it contains information for inverting the temporal demultiplexing performed at the encoder. The value '000' is reserved.

6.3.8 Group of pictures header

group_start_code – The group_start_code is the bit string '000001B8' in hexadecimal. It identifies the beginning of a group of pictures header.

time_code – This is a 25-bit integer containing the following: drop_frame_flag, time_code_hours, time_code_minutes, marker_bit, time_code_seconds and time_code_pictures as shown in Table 6-11. The parameters correspond to those defined in the IEC standard publication 60461 for "time and control codes for video tape recorders". The time code refers to the first picture after the group of pictures header that has a temporal_reference of zero. The drop_frame_flag can be set to either '0' or '1'. It may be set to '1' only if the frame rate is 29.97 Hz. If it is '0' then pictures are counted assuming rounding to the nearest integral number of pictures per second, for example 29.97 Hz would be rounded to and counted as 30 Hz. If it is '1' then picture numbers 0 and 1 at the start of each minute, except minutes 0, 10, 20, 30, 40, 50 are omitted from the count.

NOTE – The information carried by time_code plays no part in the decoding process.

Table 6-11 – time_code

time_code	Range of value	No. of bits	Mnemonic
drop_frame_flag		1	uimsbf
time_code_hours	0 - 23	5	uimsbf
time_code_minutes	0 - 59	6	uimsbf
marker_bit	1	1	bslbf
time_code_seconds	0 - 59	6	uimsbf
time_code_pictures	0 - 59	6	uimsbf

closed_gop – This is a one-bit flag which indicates the nature of the predictions used in the first consecutive B-pictures (if any) immediately following the first coded I-frame following the group of picture header.

closed_gop is set to '1' to indicate that these B-pictures have been encoded using only backward prediction or intra coding.

This bit is provided for use during any editing which occurs after encoding. If the previous pictures have been removed by editing, broken_link may be set to '1' so that a decoder may avoid displaying these B-pictures following the first I-picture following the group of picture header. However, if the closed_gop bit is set to '1', then the editor may choose not to set the broken_link bit as these B-pictures can be correctly decoded.

broken_link – This is a one-bit flag which shall be set to '0' during encoding. It is set to '1' to indicate that the first consecutive B-pictures (if any) immediately following the first coded I-frame following the group of picture header may not be correctly decoded because the reference frame which is used for prediction is not available (because of the action of editing).

A decoder may use this flag to avoid displaying frames that cannot be correctly decoded.

6.3.9 Picture header

picture_start_code – The picture_start_code is a string of 32 bits having the value 00000100 in hexadecimal.

temporal_reference – The temporal_reference is a 10-bit unsigned integer associated with each coded picture.

The following simple specification applies only when low_delay is equal to zero.

When a coded frame is in the form of two field pictures, the temporal_reference associated with each picture shall be the same (it is called the temporal_reference of the coded frame). The temporal_reference of each coded frame shall increment by one modulo 1024 when examined in display order at the output of the decoding process, except when a group of pictures header occurs. Among the frames coded after a group of pictures header, the temporal_reference of the coded frame that is displayed first, shall be set to zero.

The following more general specification applies when low_delay is equal to zero or one.

If picture A is not a big picture, i.e. the VBV buffer is only examined once before the coded picture A is removed from the VBV buffer and if N is the temporal_reference of picture A, then the temporal_reference of picture B immediately following picture A in display order is equal to:

- 0 if there is a group of pictures header present between picture A and picture B (in coded order).
- (N + 1) % 1024 if picture B is a frame picture or is the first field of a pair of field pictures.
- N if picture B is the second field of a pair of field pictures.

When low_delay is equal to one, there may be situations where the VBV buffer shall be re-examined several times before removing a coded picture (referred to as a big picture) from the VBV buffer.

If picture A is a big picture and if K is the number of times that the VBV buffer is re-examined as defined in C.7 (K > 0), if N is the temporal_reference of picture A, then the temporal_reference of picture B immediately following picture A in display order is equal to:

- K % 1024 if there is a group of pictures header present between picture A and picture B (in coded order).

- (N + K + 1) % 1024 if picture B is a frame picture or is the first field of a pair of field pictures.
- (N + K) % 1024 if picture B is the second field of a pair of field pictures.

NOTE 1 – If the big picture is the first field of a frame coded with field pictures, then the temporal_reference of the two field pictures of that coded frame are not identical.

picture_coding_type – The picture_coding_type identifies whether a picture is an intra-coded picture(I), predictive-coded picture(P) or bidirectionally predictive-coded picture(B). The meaning of picture_coding_type is defined in Table 6-12.

NOTE 2 – Intra-coded pictures with only DC coefficients (D-pictures) that may be used in ISO/IEC 11172-2 are not supported by this Specification.

Table 6-12 – picture_coding_type

picture_coding_type	coding method
000	Forbidden
001	intra-coded (I)
010	predictive-coded (P)
011	bidirectionally-predictive-coded (B)
100	Shall not be used (dc intra-coded (D) in ISO/IEC11172-2)
101	Reserved
110	Reserved
111	Reserved

vbv_delay – The vbv_delay is a 16-bit unsigned integer. In all cases other then when vbv_delay has the value hexadecimal FFFF, the value of vbv_delay is the number of periods of a 90 kHz clock derived from the 27 MHz system clock that the VBV shall wait after receiving the final byte of the picture start code before decoding the picture. vbv_delay shall be coded to represent the delay as specified above or it shall be coded with the value hexadecimal FFFF. If any vbv_delay field in a sequence is coded with hexadecimal FFFF, then all of them shall be coded with this value. If vbv_delay takes the value hexadecimal FFFF, input of data to the VBV buffer is defined in C.3.2, otherwise input to the VBV buffer is defined in C.3.1.

If low_delay is equal '1' and if the bitstream contains big pictures, the vbv_delay values encoded in the picture_header() of big pictures may be wrong if not equal to hexadecimal FFFF.

NOTE 3 – There are several ways of calculating vbv_delay in an encoder.

In all cases it may be calculated by noting that the end-to-end delay through the encoder and decoder buffer is constant for all pictures. The encoder is capable of knowing the delay experienced by the relevant picture start code in the encoder buffer and the total end-to-end delay. Therefore, the value encoded in vbv_delay (the decoder buffer delay of the picture start code) is calculated as the total delay less the delay of the corresponding picture start code in the encoder buffer measured in periods of a 90 kHz clock derived from the 27 MHz system clock.

Alternatively, for constant bit rate operation only, vbv_delay may be calculated from the state of the VBV as follows:

$$vbv\_delay_n = 90\,000 * B_n^* / R$$

where:

$n > 0$

B_n^* = VBV occupancy, measured in bits, immediately before removing picture n from the buffer but after removing any header(s), user data and stuffing that immediately precedes the data elements of picture n.

R = the actual bit rate (i.e. to full accuracy rather than the quantized value given by bit_rate in the sequence header).

An equivalent method of calculating vbv_delay for variable bit rate streams can be derived from the equation in C.3.1. This will be in the form of a recurrence relation for the vbv_delay given the previous vbv_delay, the decoding times of the current and previous pictures, and the number of bytes in the previous picture. This method can be applied if, at the time vbv_delay is encoded, the average bit rate of the transfer of the picture data of the previous picture is known.

full_pel_forward_vector – This flag that is used in ISO/IEC 11172-2 is not used by this Specification. It shall have the value '0'.

forward_f_code – This 3 bit string (which is used in ISO/IEC 11172-2) is not used by this Specification. It shall have the value '111'.

full_pel_backward_vector – This flag that is used in ISO/IEC 11172-2 is not used by this Specification. It shall have the value '0'.

backward_f_code – This 3 bit string (which is used in ISO/IEC 11172-2) is not used by this Specification. It shall have the value '111'.

extra_bit_picture – This flag indicates the presence of the following extra information. If extra_bit_picture is set to '1', content_description_data() shall follow it. If it is set to '0', no further content_description_data() shall follow in this picture header.

extra_information_picture – Reserved. A decoder conforming to this Specification that encounters extra_information_picture in a bitstream shall ignore it (i.e. remove from the bitstream and discard). A bitstream conforming to this Specification shall not contain this syntax element.

6.3.10 Picture coding extension

f_code[s][t] – A 4 bit unsigned integer taking values 1 through 9, or 15. The value zero is forbidden and the values 10 through 14 are reserved. It is used in the decoding of motion vectors, see 7.6.3.1.

In an I-picture in which concealment_motion_vectors is zero f_code[s][t] is not used (since motion vectors are not used) and shall take the value 15 (all ones).

Similarly, in an I-picture or a P-picture f_code[1][t] is not used in the decoding process (since it refers to backwards motion vectors) and shall take the value 15 (all ones).

See Table 7-7 for the meaning of the indices; s and t.

intra_dc_precision – This is a 2-bit integer defined in Table 6-13.

Table 6-13 – Intra DC precision

intra_dc_precision	Precision (bits)
00	8
01	9
10	10
11	11

The inverse quantization process for the Intra DC coefficients is modified by this parameter as explained in 7.4.1.

picture_structure – This is a 2-bit integer defined in Table 6-14.

Table 6-14 – Meaning of picture_structure

picture_structure	Meaning
00	Reserved
01	Top Field
10	Bottom Field
11	Frame picture

When a frame is encoded in the form of two field pictures both fields must be of the same picture_coding_type, except where the first encoded field is an I-picture in which case the second may be either an I-picture or a P-picture.

The first encoded field of a frame may be a top-field or a bottom field, and the next field must be of opposite parity.

When a frame is encoded in the form of two field pictures, the following syntax elements may be set independently in each field picture:

- f_code[0][0], f_code[0][1];
- f_code[1][0], f_code[1][1];
- intra_dc_precision, concealment_motion_vectors, q_scale_type;
- intra_vlc_format, alternate_scan;
- vbv_delay;
- temporal_reference.

top_field_first – The meaning of this element depends upon picture_structure, progressive_sequence and repeat_first_field.

If progressive_sequence is equal to '0', this flag indicates what field of a reconstructed frame is output first by the decoding process.

In a field picture top_field_first shall have the value '0', and the only field output by the decoding process is the decoded field picture.

In a frame picture top_field_first being set to '1' indicates that the top field of the reconstructed frame is the first field output by the decoding process. top_field_first being set to '0' indicates that the bottom field of the reconstructed frame is the first field output by decoding process.

If progressive_sequence is equal to '1', this flag, combined with repeat_first_field, indicates how many times (one, two or three) the reconstructed frame is output by the decoding process.

If repeat_first_field is set to 0, top_field_first shall be set to '0'. In this case the output of the decoding process corresponding to this reconstructed frame consists of one progressive frame.

If top_field_first is set to 0 and repeat_first_field is set to '1', the output of the decoding process corresponding to this reconstructed frame consists of two identical progressive frames.

If top_field_first is set to 1 and repeat_first_field is set to '1', the output of the decoding process corresponding to this reconstructed frame consists of three identical progressive frames.

frame_pred_frame_dct – If this flag is set to '1', then only frame-DCT and frame prediction are used. In a field picture it shall be '0'. frame_pred_frame_dct shall be '1' if progressive_sequence is '1'. This flag affects the syntax of the bitstream.

concealment_motion_vectors – This flag has the value '1' to indicate that motion vectors are coded in intra macroblocks. This flag has the value '0' to indicate that no motion vectors are coded in intra macroblocks.

q_scale_type – This flag affects the inverse quantization process as described in 7.4.2.2.

intra_vlc_format – This flag affects the decoding of transform coefficient data as described in 7.2.2.1.

alternate_scan – This flag affects the decoding of transform coefficient data as described in 7.3.

repeat_first_field – This flag is applicable only in a frame picture; in a field picture it shall be set to zero and does not affect the decoding process.

If progressive_sequence is equal to 0 and progressive_frame is equal to 0, repeat_first_field shall be zero, and the output of the decoding process corresponding to this reconstructed frame consists of two fields.

If progressive_sequence is equal to 0 and progressive_frame is equal to 1:

If this flag is set to 0, the output of the decoding process corresponding to this reconstructed frame consists of two fields. The first field (top or bottom field as identified by top_field_first) is followed by the other field.

If it is set to 1, the output of the decoding process corresponding to this reconstructed frame consists of three fields. The first field (top or bottom field as identified by top_field_first) is followed by the other field, then the first field is repeated.

If progressive_sequence is equal to 1:

If this flag is set to 0, the output of the decoding process corresponding to this reconstructed frame consists of one frame.

If it is set to 1, the output of the decoding process corresponding to this reconstructed frame consists of two or three frames, depending on the value of top_field_first.

chroma_420_type – If chroma_format is "4:2:0", the value of chroma_420_type shall be the same as progressive_frame; else chroma_420_type has no meaning and shall be equal to zero. This flag exists for historical reasons.

progressive_frame – If progressive_frame is set to 0 it indicates that the two fields of the frame are interlaced fields in which an interval of time of the field period exists between (corresponding spatial samples) of the two fields. In this case the following restriction applies:

- repeat_first_field shall be zero (two field duration).

If progressive_frame is set to 1 it indicates that the two fields (of the frame) are actually from the same time instant as one another. In this case a number of restrictions to other parameters and flags in the bitstream apply:

- picture_structure shall be "Frame";
- if progressive_sequence is equal to one, then frame_pred_frame_dct shall be 1.

progressive_frame is used when the video sequence is used as the lower layer of a spatial scalable sequence. Here it affects the up-sampling process used in forming a prediction in the enhancement layer from the lower layer.

composite_display_flag – This flag is set to 1 to indicate that the following fields that are of use when the input pictures have been coded as (analogue) composite video prior to encoding into a bitstream that complies with this Specification. If it is set to 0, then these parameters do not occur in the bitstream.

The information relates to the picture that immediately follows the extension. In the case that this picture is a frame picture, the information relates to the first field of that frame. The equivalent information for the second field may be derived (there is no way to represent it in the bitstream).

NOTE 1 – The various syntactic elements that are included in the bitstream if composite_display_flag is '1' are not used in the decoding process.

NOTE 2 – repeat_first_field will cause a composite video field to be repeated out of the 4-field or 8-field sequence. It is recommended that repeat_first_field and composite_display_flag are not both set simultaneously.

v_axis – A 1-bit integer used only when the bitstream represents a signal that had previously been encoded according to PAL systems. v_axis is set to 1 on a positive sign, v_axis is set to 0 otherwise.

field_sequence – A 3-bit integer which defines the number of the field in the eight field sequence used in PAL systems or the four field sequence used in NTSC systems as defined in Table 6-15.

Table 6-15 – Definition of field_sequence

Field sequence	Frame	Field
000	1	1
001	1	2
010	2	3
011	2	4
100	3	5
101	3	6
110	4	7
111	4	8

sub_carrier – This is a 1-bit integer. Set to 0 means the sub-carrier/line frequency relationship is correct. When set to 1 the relationship is not correct.

burst_amplitude – This is a 7-bit integer defining the burst amplitude (for PAL and NTSC only). The amplitude of the sub-carrier burst is quantized as a Recommendation ITU-R BT.601 luminance signal, with the MSB omitted.

sub_carrier_phase – This is an 8-bit integer defining the phase of the reference sub-carrier at the field-synchronisation datum with respect to field start, as defined in Recommendation ITU-R BT.470 (see Table 6-16).

Table 6-16 – Definition of sub_carrier_phase

sub_carrier_phase	Phase
0	([360° ÷ 256] * 0)
1	([360° ÷ 256] * 1)
…	…
255	([360° ÷ 256] * 255)

6.3.11 Quant matrix extension

Each quantization matrix has a default set of values. When a sequence_header_code is decoded all matrices shall be reset to their default values. User defined matrices may be downloaded and this can occur in a sequence_header() or in a quant_matrix_extension().

With 4:2:0 data only two matrices are used, one for intra blocks the other for non-intra blocks.

With 4:2:2 or 4:4:4 data four matrices are used. Both an intra and a non-intra matrix are provided for both luminance blocks and for chrominance blocks. Note, however, that it is possible to download the same user defined matrix into both the luminance and chrominance matrix at the same time.

The default matrix for intra blocks (both luminance and chrominance) is:

									u
		0	1	2	3	4	5	6	7
	0	8	16	19	22	26	27	29	34
	1	16	16	22	24	27	29	34	37
	2	19	22	26	27	29	34	34	38
	3	22	22	26	27	29	34	37	40
	4	22	26	27	29	32	35	40	48
	5	26	27	29	32	35	40	48	58
	6	26	27	29	34	38	46	56	69
v	7	27	29	35	38	46	56	69	83

Figure 6-16 – Default matrix for intra blocks

The default matrix for non-intra blocks (both luminance and chrominance) is:

									u
		0	1	2	3	4	5	6	7
	0	16	16	16	16	16	16	16	16
	1	16	16	16	16	16	16	16	16
	2	16	16	16	16	16	16	16	16
	3	16	16	16	16	16	16	16	16
	4	16	16	16	16	16	16	16	16
	5	16	16	16	16	16	16	16	16
	6	16	16	16	16	16	16	16	16
v	7	16	16	16	16	16	16	16	16

Figure 6-17 – Default matrix for non-intra blocks

load_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used.

intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. The first value shall always be 8 (values 1 to 7 and 9 to 255 are reserved). For all of the 8-bit unsigned integers, the value zero is forbidden. With 4:2:2 and 4:4:4 data the new values shall be used for both the luminance intra matrix and the chrominance intra matrix. However, the chrominance intra matrix may subsequently be loaded with a different matrix.

load_non_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if non_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used.

non_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. For all the 8-bit unsigned integers, the value zero is forbidden. With 4:2:2 and 4:4:4 data, the new values shall be used for both the luminance non-intra matrix and the chrominance non-intra matrix. However, the chrominance non-intra matrix may subsequently be loaded with a different matrix.

load_chroma_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if chroma_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used. If chroma_format is "4:2:0", this flag shall take the value '0'.

chroma_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. The first value shall always be 8 (values 1 to 7 and 9 to 255 are reserved). For all of the 8-bit unsigned integers, the value zero is forbidden.

load_chroma_non_intra_quantiser_matrix – This is a one-bit flag which is set to '1' if chroma_non_intra_quantiser_matrix follows. If it is set to '0' then there is no change in the values that shall be used. If chroma_format is "4:2:0", this flag shall take the value '0'.

chroma_non_intra_quantiser_matrix – This is a list of sixty-four 8-bit unsigned integers. The new values, encoded in the default zigzag scanning order as described in 7.3.1, replace the previous values. For all the 8-bit unsigned integers, the value zero is forbidden.

6.3.12 Picture display extension

This Specification does not define the display process. The information in this extension does not affect the decoding process and may be ignored by decoders that conform to this Specification.

The picture display extension allows the position of the display rectangle whose size is specified in sequence_display_extension() to be moved on a picture-by-picture basis. One application for this is the implementation of pan-scan.

frame_centre_horizontal_offset – This is a 16-bit signed integer giving the horizontal offset in units of 1/16th sample. A positive value shall indicate that the centre of the reconstructed frame lies to the right of the centre of the display rectangle.

frame_centre_vertical_offset – This is a 16-bit signed integer giving the vertical offset in units of 1/16th sample. A positive value shall indicate that the centre of the reconstructed frame lies below the centre of the display rectangle.

The dimensions of the display rectangular region are defined in the sequence_display_extension(). The coordinates of the region within the coded picture are defined in the picture_display_extension().

The centre of the reconstructed frame is the centre of the rectangle defined by horizontal_size and vertical_size.

Since (in the case of an interlaced sequence) a coded picture may relate to one, two or three decoded fields, the picture_display_extension() may contain up to three offsets.

The number of frame centre offsets in the picture_display_extension() shall be defined as follows:

```
if ( progressive_sequence == 1) {
    if ( repeat_first_field == '1' ) {
        if ( top_field_first == '1' )
            number_of_frame_centre_offsets = 3
        else
            number_of_frame_centre_offsets = 2
    } else {
        number_of_frame_centre_offsets = 1
    }
} else {
    if (picture_structure == "field") {
        number_of_frame_centre_offsets = 1
    } else {
        if (repeat_first_field == '1' )
```

```
                number_of_frame_centre_offsets = 3
            else
                number_of_frame_centre_offsets = 2
        }
    }
```

A picture_display_extension() shall not occur unless a sequence_display_extension() followed the previous sequence_header().

In the case that a given picture does not have a picture_display_extension(), then the most recently decoded frame centre offset shall be used. Note that each of the missing frame centre offsets have the same value (even if two or three frame centre offsets would have been contained in the picture_display_extension() had been present). Following a sequence_header() the value zero shall be used for all frame centre offsets until a picture_display_extension() defines non-zero values.

Figure 6-18 illustrates the picture display parameters. As shown, the frame centre offsets contained in the picture_display_extension() shall specify the position of the centre of the reconstructed frame from the centre of the display rectangle.

NOTE 1 – The display rectangle may also be larger than the reconstructed frame.

NOTE 2 – Even in a field picture the frame_centre_vertical_offset still represents the offset of the centre of the frame in 1/16th of a **frame** line (not a line in the field).

NOTE 3 – In the example of Figure 6-17 both frame_centre_horizontal_offset and frame_centre_vertical_offset have negative values.

6.3.12.1 Pan-scan

The frame centre offsets may be used to implement pan-scan in which a rectangular region is defined which may be panned around the entire reconstructed frame.

By way of example only; this facility may be used to identify a 4:3 aspect ratio window in a 16:9 coded picture format. This would allow a decoder to produce usable pictures for a conventional definition television set from an encoded format intended for enhanced definition. The 4:3 aspect ratio region is intended to contain the "most interesting" region of the picture.

The 4:3 aspect ratio region is defined by display_horizontal_size and display_vertical_size. The 16:9 frame size is defined by horizontal_size and vertical_size.

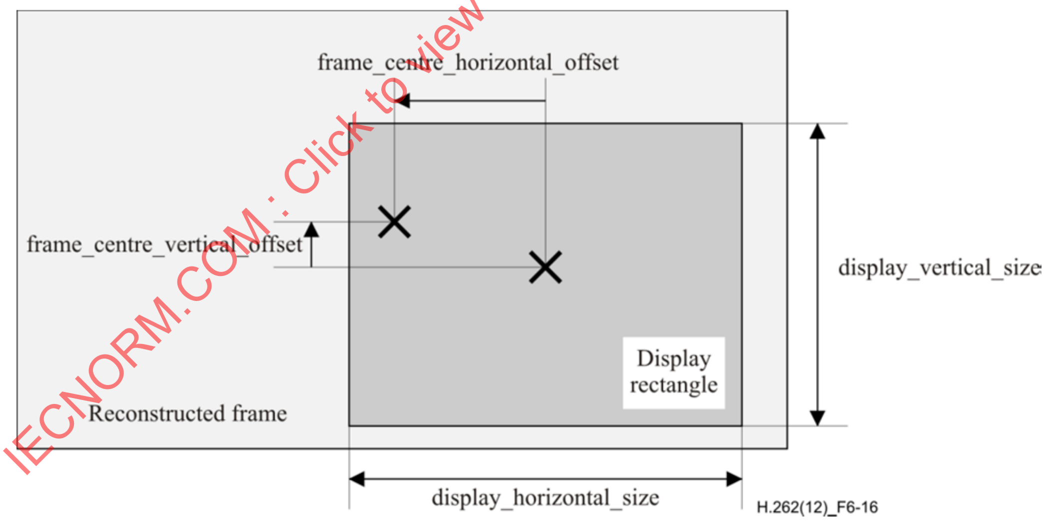


Figure 6-18 – Frame centre offset parameters

6.3.13 Picture temporal scalable extension

NOTE – See also 7.9.

reference_select_code – This is a 2-bit code that identifies reference frames or reference fields for prediction depending on the picture type.

forward_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the forward prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

backward_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the backward prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

6.3.14 Picture spatial scalable extension

lower_layer_temporal_reference – A 10 bit unsigned integer value which indicates temporal reference of the lower layer frame to be used to provide the prediction. If the lower layer indicates temporal reference with more than 10 bits, the least significant bits are encoded here. If the lower layer indicates temporal reference with fewer than 10 bits, all bits are encoded here and the more significant bits shall be set to zero.

lower_layer_horizontal_offset – This 15 bit signed (two's complement) integer specifies the horizontal offset (of the top left hand corner) of the upsampled lower layer frame relative to the enhancement layer picture. It is expressed in units of the enhancement layer picture sample width. If the chrominance format is 4:2:0 or 4:2:2, then this parameter shall be an even number.

lower_layer_vertical_offset – This 15 bit signed (two's complement) integer specifies the vertical offset (of the top left hand corner) of the upsampled lower layer picture relative to the enhancement layer picture. It is expressed in units of the enhancement layer picture sample height. If the chrominance format is 4:2:0, then this parameter shall be an even number.

spatial_temporal_weight_code_table_index – This 2-bit integer indicates which table of spatial temporal weight codes is to be used as defined in 7.7. Permissible values of spatial_temporal_weight_code_table_index are defined in Table 7-21.

lower_layer_progressive_frame – This flag shall be set to 0 if the lower layer frame is interlaced and shall be set to '1' if the lower layer frame is progressive. The use of this flag in the spatial scalable upsampling process is defined in 7.7.

lower_layer_deinterlaced_field_select – This flag affects the spatial scalable upsampling process, as defined in 7.7.

6.3.15 Copyright extension

extension_start_code_identifier – This is a 4-bit integer which identifies the extension (see Table 6-2).

copyright_flag – This is a one bit flag. When copyright_flag is set to '1', it indicates that the source video material encoded in all the coded pictures following the copyright extension, in coding order, up to the next copyright extension or end of sequence code, is copyrighted. The copyright_identifier and copyright_number identify the copyrighted work. When copyright_flag is set to '0', it does not indicate whether the source video material encoded in all the coded pictures following the copyright extension, in coding order, is copyrighted or not.

copyright_identifier – This is an 8-bit integer given by a Registration Authority as designated by ISO/IEC JTC1/SC29. Value zero indicates that this information is not available. The value of copyright_number shall be zero when copyright_identifier is equal to zero.

When copyright_flag is set to '0', copyright_identifier has no meaning and shall have the value 0.

original_or_copy – This is a one bit flag. It is set to '1' to indicate that the material is an original, and set to '0' to indicate that it is a copy.

reserved – This is a 7-bit integer, reserved for future extension. It shall have the value zero.

copyright_number_1 – This is a 20-bit integer, representing bits 44 to 63 of copyright_number.

copyright_number_2 – This is a 22-bit integer, representing bits 22 to 43 of copyright_number.

copyright_number_3 – This is a 22-bit integer. representing bits 0 to 21 of copyright_number.

copyright_number – This is a 64-bit integer, derived from copyright_number_1, copyright_number_2, and copyright_number_3 as follows:

copyright_number = (copyright_number_1 << 44) + (copyright_number_2 << 22) + copyright_number_3.

The meaning of copyright_number is defined only when copyright_flag is set to '1'. In this case, the value of copyright_number identifies uniquely the copyrighted work marked by the copyrighted extension. The value 0 for copyright_number indicates that the identification number of the copyrighted work is not available.

When copyright_flag is set to '0', copyright_number has no meaning and shall have the value 0.

6.3.16 Slice

slice_start_code – The slice_start_code is a string of 32-bits. The first 24-bits have the value 000001 in hexadecimal and the last 8-bits are the slice_vertical_position having a value in the range 01 through AF hexadecimal inclusive.

slice_vertical_position – This is given by the last eight bits of the slice_start_code. It is an unsigned integer giving the vertical position in macroblock units of the first macroblock in the slice.

In large pictures (when the vertical size of the frame is greater than 2800 lines) the slice vertical position is extended by the **slice_vertical_position_extension**.

The macroblock row may be calculated as follows:

```
if ( vertical_size > 2800 )
        mb_row = (slice_vertical_position_extension << 7) + slice_vertical_position –1;
    else
        mb_row = slice_vertical_position –1;
```

The slice_vertical_position of the first row of macroblocks is one. Some slices may have the same slice_vertical_position, since slices may start and finish anywhere. The maximum value of slice_vertical_position is 175 unless slice_vertical_position_extension is present in which case slice_vertical_position shall be in the range [1:128].

priority_breakpoint – This is a 7-bit integer that indicates the point in the syntax where the bitstream shall be partitioned. The allowed values and their semantic interpretation is given in Table 7-30 priority_breakpoint shall take the value zero in partition 1.

quantiser_scale_code – A 5 bit unsigned integer in the range 1 to 31. The decoder shall use this value until another quantiser_scale_code is encountered either in slice() or macroblock(). The value zero is forbidden.

slice_extension_flag – This flag shall be set to '1' to indicate the presence of intra_slice, slice_picture_id_enable, slice_picture_id in the bitstream.

intra_slice – This flag shall be set to '0' if any of the macroblocks in the slice are non-intra macroblocks. If all of the macroblocks, are intra macroblocks, then intra_slice may be set to '1'.

intra_slice may be omitted from the bitstream (by setting intra_slice_flag to '0') in which case it shall be assumed to have the value zero.

intra_slice is not used by the decoding process. intra_slice is intended to aid a DSM application in performing FF/FR (see F.12).

slice_picture_id_enable – This flag controls the semantics of slice_picture_id. If slice_picture_id_enable is set to '0', slice_picture_id is not used by this Specification and shall have the value zero. If slice_picture_id_enable is set to '1', slice_picture_id may have a value different from zero.

slice_picture_id_enable must have the same value in all the slices of a picture. slice_picture_id_enable may be omitted from the bitstream (by setting slice_extension_flag to '0') in which case it shall be assumed to have the value zero.

slice_picture_id_enable is not used by the decoding process.

slice_picture_id – This is a 6-bit integer. If slice_picture_id_enable is set to '0', slice_picture_id is not used by this Specification and shall have the value zero. If slice_picture_id_enable is set to '1', slice_picture_id is application defined and may have any value, with the constraint that slice_picture_id shall have the same value in all the slices of a picture.

slice_picture_id is not used by the decoding process. slice_picture_id is intended to aid recovery on severe bursts of errors for certain types of applications. For example, the application may increment slice_picture_id with each transmitted picture, so that in case of severe burst error, when several slices are lost, the decoder can know if the slice following the burst error belongs to the current picture or to another picture, which may be the case if at least a picture header has been lost.

extra_bit_slice – This flag indicates the presence of the following extra information. If extra_bit_slice is set to '1', extra_information_slice will follow it. If it is set to '0', there are no data following it. extra_bit_slice shall be set to '0', the value '1' is reserved for possible future extensions defined by ITU-T | ISO/IEC.

extra_information_slice – Reserved. A decoder conforming to this Specification that encounters extra_information_slice in a bitstream shall ignore it (i.e. remove from the bitstream and discard). A bitstream conforming to this Specification shall not contain this syntax element.

6.3.17 Macroblock

NOTE – "macroblock_stuffing" which is supported in ISO/IEC 11172-2 shall not be used in a bitstream defined by this Specification.

macroblock_escape – The macroblock_escape is a fixed bit-string '0000 0001 000' which is used when the difference between macroblock_address and previous_macroblock_address is greater than 33. It causes the value of macroblock_address_increment to be 33 greater than the value that will be decoded by subsequent macroblock_escape and the macroblock_address_increment codewords.

For example, if there are two macroblock_escape codewords preceding the macroblock_address_increment, then 66 is added to the value indicated by macroblock_address_increment.

macroblock_address_increment – This is a variable length coded integer coded as per Table B.1 which indicates the difference between macroblock_address and previous_macroblock_address. The maximum value of macroblock_address_increment is 33. Values greater than this can be encoded using the macroblock_escape codeword.

The macroblock_address is a variable defining the absolute position of the current macroblock. The macroblock_address of the top-left macroblock is zero.

The previous_macroblock_address is a variable defining the absolute position of the last non-skipped macroblock (see 7.6.6 for the definition of skipped macroblocks) except at the start of a slice. At the start of a slice previous_macroblock_address is reset as follows:

$$\text{previous\_macroblock\_address} = (\text{mb\_row} * \text{mb\_width}) - 1$$

The horizontal spatial position in macroblock units of a macroblock in the picture (mb_column) can be computed from the macroblock_address as follows:

$$\text{mb\_column} = \text{macroblock\_address} \,\%\, \text{mb\_width}$$

where mb_width is the number of macroblocks in one row of the picture.

Except at the start of a slice, if the value of macroblock_address recovered from macroblock_address_increment and the macroblock_escape codes (if any) differs from the previous_macroblock_address by more than one then some macroblocks have been skipped. It is a requirement that:

- There shall be no skipped macroblocks in I-pictures except when either
  - picture_spatial_scalable_extension() follows the picture_header() of the current picture; or
  - sequence_scalable_extension() is present in the bitstream and scalable_mode = "SNR scalability".
- In a B-picture there shall be no skipped macroblocks immediately following a macroblock in which macroblock_intra is one.

It should be noted that the syntax does not allow the first and last macroblock of a slice to be skipped.

6.3.17.1 Macroblock modes

macroblock_type – Variable length coded indicator which indicates the method of coding and content of the macroblock according to Tables B.2 through B.8, selected by picture_coding_type and scalable_mode.

macroblock_quant – Derived from macroblock_type according to Tables B.2 through B.8. This is set to 1 to indicate that quantiser_scale_code is present in the bitstream.

macroblock_motion_forward – Derived from macroblock_type according to Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

macroblock_motion_backward – Derived from macroblock_type according to Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

macroblock_pattern – Derived from macroblock_type according to Tables B.2 through B.8. This is set to 1 to indicate that coded_block_pattern() is present in the bitstream.

macroblock_intra – Derived from macroblock_type according to Tables B.2 through B.8. This flag affects the bitstream syntax and is used by the decoding process.

spatial_temporal_weight_code_flag – Derived from the macroblock_type. This indicates whether the spatial_temporal_weight_code is present in the bitstream.

When spatial_temporal_weight_code_flag is '0' (indicating that spatial_temporal_weight_code is not present in the bitstream) the spatial_temporal_weight_class is derived from Tables B.5 to B.7. When spatial_temporal_weight_code_flag is '1' spatial_temporal_weight_class is derived from Table 7-20.

spatial_temporal_weight_code – This is a two bit code which indicates, in the case of spatial scalability, how the spatial and temporal predictions shall be combined to form the prediction for the macroblock. A full description of how to form the spatial scalable prediction is given in 7.7.

frame_motion_type – This is a two bit code indicating the macroblock prediction type, defined in Table 6-17.

Table 6-17 – Meaning of frame_motion_type

Code	**spatial_temporal _weight_class**	Prediction type	**motion_vector _count**	**mv_format**	dmv
00		Reserved			
01	0, 1	Field-based	2	Field	0
01	2, 3	Field-based	1	Field	0
10	0, 1, 2, 3	Frame-based	1	Frame	0
11	0, 2, 3	Dual-Prime	1	Field	1

If frame_pred_frame_dct is equal to 1 then frame_motion_type is omitted from the bitstream. In this case motion vector decoding and prediction formation shall be performed as if frame_motion_type had indicated "Frame-based prediction".

In the case of intra macroblocks (in a frame picture) when concealment_motion_vectors is equal to 1 frame_motion_type is not present in the bitstream. In this case motion vector decoding and update of the motion vector predictors shall be performed as if frame_motion_type had indicated "Frame-based" (see 7.6.3.9).

field_motion_type – This is a two bit code indicating the macroblock prediction type, defined in Table 6-18.

Table 6-18 – Meaning of field_motion_type

Code	**spatial_temporal _weight_class**	Prediction type	**motion_vector _count**	**mv_format**	dmv
00		Reserved			
01	0, 1	Field-based	1	Field	0
10	0, 1	16 × 8 MC	2	Field	0
11	0	Dual-Prime	1	Field	1

In the case of intra macroblocks (in a field picture) when concealment_motion_vectors is equal to 1 field_motion_type is not present in the bitstream. In this case, motion vector decoding and update of the motion vector predictors shall be performed as if field_motion_type had indicated "Field-based" (see 7.6.3.9).

dct_type – This is a flag indicating whether the macroblock is frame DCT coded or field DCT coded. If this is set to '1', the macroblock is field DCT coded.

In the case that **dct_type** is not present in the bitstream, then the value of dct_type (used in the remainder of the decoding process) shall be derived as shown in Table 6-19.

Table 6-19 – Value of dct_type if dct_type is not in the bitstream

Condition	**dct_type**
picture_structure == "field"	Unused because there is no frame/field distinction in a field picture.
frame_pred_frame_dct == 1	0 ("frame")
!(macroblock_intra || macroblock_pattern)	Unused – Macroblock is not coded
macroblock is skipped	Unused – Macroblock is not coded

6.3.17.2 Motion vectors

motion_vector_count is derived from field_motion_type or frame_motion_type as indicated in Tables 6-17 and 6-18.

mv_format is derived from field_motion_type or frame_motion_type as indicated in Tables 6-17 and 6-18. mv_format indicates if the motion vector is a field-motion vector or a frame-motion vector. mv_format is used in the syntax of the motion vectors and in the process of motion vector prediction.

dmv is derived from field_motion_type or frame_motion_type as indicated in Tables 6-17 and 6-18.

motion_vertical_field_select[r][s] – This flag indicates which reference field shall be used to form the prediction. If motion_vertical_field_select[r][s] is zero, then the top reference field shall be used, if it is one then the bottom reference field shall be used. (See Table 7-7 for the meaning of the indices r and s.)

6.3.17.3 Motion vector

motion_code[r][s][t] – This is a variable length code, as defined in Table B.10, which is used in motion vector decoding as described in 7.6.3.1. (See Table 7-7 for the meaning of the indices r, s and t.)

motion_residual[r][s][t] – This is an integer which is used in motion vector decoding as described in 7.6.3.1. (See Table 7-7 for the meaning of the indices r, s and t.) The number of bits in the bitstream for motion_residual[r][s][t], r_size, is derived from f_code[s][t] as follows:

$$r\_size = f\_code[s][t] - 1$$

NOTE – The number of bits for both motion_residual[0][s][t] and motion_residual[1][s][t] is denoted by f_code[s][t].

dmvector[t] – This is a variable length code, as defined in Table B.11, which is used in motion vector decoding as described in 7.6.3.6. (See Table 7-7 for the meaning of the index t.)

6.3.17.4 Coded block pattern

coded_block_pattern_420 – A variable length code that is used to derive the variable cbp according to Table B.9.

coded_block_pattern_1

coded_block_pattern_2 – For 4:2:2 and 4:4:4 data the coded block pattern is extended by the addition of either a two bit or six bit fixed length code, coded_block_pattern_1 or coded_block_pattern_2. Then the pattern_code[i] is derived using the following:

```
for (i = 0; i < 12; i++) {
      if (macroblock_intra)
            pattern_code[i] = 1;
      else
            pattern_code[i] = 0;
}
if (macroblock_pattern) {
      for (i = 0; i < 6; i++)
            if ( cbp & (1<<(5 – i)) ) pattern_code[i] = 1;
      if (chroma_format == "4:2:2")
            for (i = 6; i < 8; i++)
                  if ( coded_block_pattern_1 & (1<<(7 – i)) ) pattern_code[i] = 1;
      if (chroma_format == "4:4:4")
            for (i = 6; i < 12; i++)
                  if ( coded_block_pattern_2 & (1<<(11 – i)) ) pattern_code[i] = 1;
}
```

If pattern_code[i] equals to 1, i = 0 to (block_count-1), then the block number i defined in Figures 6-10, 6-11 and 6-12 is contained in this macroblock.

The number "block_count" which determines the number of blocks in the macroblock is derived from the chrominance format as shown in Table 6-20.

Table 6-20 – block_count as a function of chroma_format

chroma_format	block_count
4:2:0	6
4:2:2	8
4:4:4	12

6.3.18 Block

The semantics of block() are described in clause 7.

6.3.19 Camera parameters extension

camera_id – The number in camera_id identifies a camera.

height_of_image_device – This is a 22-bit unsigned integer which specifies the height of image device. Its value shall be measured to a resolution of 0.001 millimeter and having a range of zero to 4 194.303 mm.

focal_length – This is a 22-bit unsigned integer which specifies the focal length. Its value shall be measured to a resolution of 0.001 millimeter and having a range of zero to 4 194.303 mm.

f_number – This is a 22-bit unsigned integer which specifies the F-number. F-number is defined by (focal_length)/(effective aperture of lens). Its value shall be measured to a resolution of 0.001 and having a range of zero to 4 194.303.

vertical_angle_of_view – This is a 22-bit unsigned integer which specifies the vertical angle of the field of view as determined between the top and bottom edges of the image device. Its value shall be measured to a resolution of 0.0001 degree and having a range of zero to 180 degrees.

camera_position_x_upper, camera_position_y_upper, camera_position_z_upper – These words constitute the 16 most significant bits of camera_position_x, camera_position_y and camera_position_z respectively.

camera_position_x_lower, camera_position_y_lower, camera_position_z_lower – These words constitute the 16 least significant bits of camera_position_x, camera_position_y and camera_position_z respectively.

camera_position_x, camera_position_y, camera_position_z – A set of these values specifies the position of the optical principal point of the camera in a user-specified world coordinate system. Each of these values shall be measured to a resolution of 0,001 millimeter and having a range of +2 147 483.647 mm to –2 147 483.648 mm. The camera_position_x is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_x_lower, the 16 most significant bits are defined in camera_position_x_upper. The camera_position_y is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_y_lower, the 16 most significant bits are defined in camera_position_y_upper. The camera_position_z is a 32-bit signed (two's complement) integer, the 16 least significant bits are defined in camera_position_z_lower, the 16 most significant bits are defined in camera_position_z_upper.

camera_direction_x, camera_direction_y, camera_direction_z – A set of these values specifies the direction of the camera. The direction of the camera is defined by using the vector from optical principal point to a point which is in front of the camera and is on the optical axis of the camera. Each of these values is a 22-bit signed (two's complement) integer and having a range of +2 097 151 to –2 097 152.

image_plane_vertical_x, image_plane_vertical_y, image_plane_vertical_z – A set of these values specifies the upper direction of the camera. The upper direction of the camera is defined by using the vector which is parallel to the side edge of the image device and is from bottom edge to top edge. Each of these values is a 22-bit signed (two's complement) integer and is having a range of +2 097 151 to –2 097 152.

Figure 6-19 explains these terms pictorially.

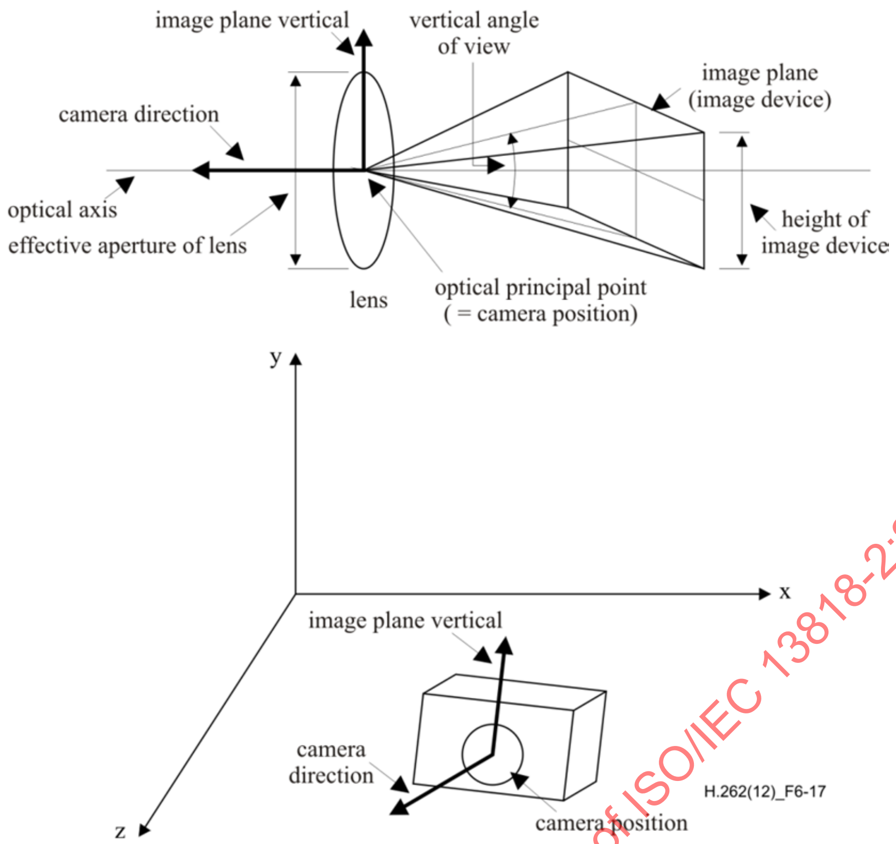


Figure 6-19 – Camera parameters

6.3.20 ITU-T extension

The use of this extension is defined in Annex A of Rec. ITU-T H.320.

6.3.21 Content description data

data_type_upper, data_type_lower – Two 8-bit unsigned integer values containing the most significant and least significant bits, respectively, of the value of the 16-bit unsigned integer **data_type** that defines the type of content description data. The semantics of **data_type** are defined in Table 6-21.

Table 6-21 – data_type values

Value	Meaning
0000 0000 0000 0000	reserved
0000 0000 0000 0001	padding bytes
0000 0000 0000 0010	capture timecode
0000 0000 0000 0011	additional pan-scan parameters
0000 0000 0000 0100	active region window
0000 0000 0000 0101	coded picture length
0000 0000 0000 0110	reserved
…	reserved
1111 1111 1111 1111	reserved

data_length – An 8-bit unsigned integer specifying the remaining amount of data to follow within the remainder of the content description data structure, expressed in units of 9 bits. The number of bits of data that follow within the remainder of the content description data structure shall be equal to data_length * 9.

reserved_content_description_data – Reserved 8-bit unsigned integer. A decoder that encounters reserved_content_description_data in a bitstream shall ignore it (i.e. remove from the bitstream and discard). A bitstream conforming to this Specification shall not contain this syntax element.

In the case that a decoder encounters a data_type unsigned integer that is described as "reserved" in Table 6-21, the decoder shall discard the subsequent pairings of marker_bit and reserved_content_description_data which follow data_length in the bitstream. The number of such pairings shall be equal to data_length. This requirement allows future definition of compatible extensions to this Specification.

reserved_bit – Reserved 1-bit unsigned integer. It shall be equal to '0' in bitstreams conforming to this Specification. The value '1' is reserved for future backward-compatible use by ITU-T | ISO/IEC. A decoder conforming to this Specification shall allow either a value of '0' or '1' for reserved_bit.

6.3.21.1 Padding bytes

padding_byte – An 8-bit string, which shall be equal to '0000 0000'. All other values are forbidden.

NOTE – The purpose of padding bytes is to allow inclusion of a number of bytes of data that are included in VBV calculations.

6.3.21.2 Capture timecode

The capture timecode describes the source capture or creation time of the fields or frames of the content.

It contains absolute timestamps for the associated frame or fields. Only one capture timecode for each picture shall be present in the bitstream. This timecode shall not take precedence over any timecode specified for presentation or decoding at a systems multiplex level, for example the presentation time stamps or decoding time stamps defined in Rec. ITU-T H.222.0 | ISO/IEC 13818-1 [6].

timecode_type – A 2-bit integer that indicates the number of timestamps associated with this picture as defined in Table 6-22. The values '00', '10', and '11' shall only be used when picture_structure is equal to 'Frame-picture'. The value '00' indicates that the two fields that make up the frame have the same capture time. When timecode_type is equal to '11', the first timestamp pertains to the first field of the frame and the second timestamp pertains to the second field of the frame.

Table 6-22 – timecode_type values

Value	Meaning
00	one timestamp for the frame
01	one timestamp for the first or only field
10	one timestamp for the second field
11	two timestamps, one for each of two fields

counting_type – A 3-bit integer that indicates the method used for compensating the nframes parameter of the frame or field capture timestamps to reduce drift accumulation in the remaining parameters of each timestamp.

Table 6-23 – counting_type values

Value	Meaning
000	nframes parameter not used
001	no dropping of nframes count values
010	dropping of individual zero values of nframes count
011	dropping of individual max_nframes values of nframes count
100	dropping of the two lowest (values 0 and 1) nframes counts when units_of_seconds and tens_of_seconds are zero and units_of_minutes is not zero
101	dropping of unspecified individual nframes count values
110	dropping of unspecified numbers of unspecified nframes count values
111	reserved

nframes_conversion_code – A 1-bit unsigned integer that indicates a conversion factor to be used in determining the amount of time indicated by the nframes parameters of each frame or field capture timestamp. The factor specified is 1000 + nframes_conversion_code.

clock_divisor – A 7-bit unsigned integer that contains the number of divisions of the 27 MHz system clock to be applied for generating the equivalent timestamp for each frame or field capture timestamp.

nframes_multiplier_upper, nframes_multiplier_lower – The most significant and least significant bits, respectively, of nframes_multiplier.

nframes_multiplier – An unsigned integer multiplier used for generating the equivalent timestamp for each frame or field capture timestamp as specified by nframes_multiplier_upper and nframes_multiplier_lower.

6.3.21.2.1 Frame or field capture timestamp

nframes – An 8-bit unsigned integer containing the number of frame time increments to add in deriving the equivalent timestamp. The value of nframes shall not be greater than the value of max_nframes as derived by the following formula:

max_nframes = (26 999 999) / (nframes_multiplier * (1000 + nframes_conversion_code) * clock_divisor)

where "/" indicates the division operator defined in 4.1.

time_discontinuity – A 1-bit flag that indicates if a discontinuity in time or timebase between the previous timestamp and the current timestamp has occurred. If set to '0', the time difference that can be calculated between the current and previous timestamps is the ideal display duration of the previous frame or field. If set to '1', the time difference that can be calculated between the current and previous timestamps has no defined meaning. If editing occurs that results in time or timebase discontinuities or if the previous field or frame timestamp is unavailable, the time_discontinuity bit shall be set to '1'.

prior_count_dropped – A 1-bit flag indicating whether the counting of one or more values of the nframes parameter was dropped in order to reduce drift accumulation in the remaining parameters of the timestamp. Shall be zero if counting_type is '001'. Shall be zero if counting_type is '010' and nframes is not equal to 1. Shall be zero if counting_type is '011' and nframes is not equal to 0. Shall be zero if counting_type is '100' and nframes is not equal to 2.

time_offset_part_a – A 6-bit integer containing the most significant bits of time_offset.

time_offset_part_b – An 8-bit unsigned integer containing the second most significant bits of time_offset.

time_offset_part_c – An 8 bit unsigned integer containing the third most significant bits of time_offset.

time_offset_part_d – An 8-bit unsigned integer containing the least significant bits of time_offset.

time_offset – A two's complement signed 30-bit integer that is the number of clock cycles (in original 27 MHz system clock cycles or with a clock frequency modified by clock_divisor) offset from the time specified by the other parameters of the frame or field capture timestamp in order to specify the equivalent timestamp for when the current field or frame was captured. When counting_type is 0, the value of time_offset shall be constrained by the encoder to be less than 27 000 000 in magnitude.

units_of_seconds – A 4-bit unsigned integer that is used to calculate the equivalent timestamp. It represents the portion of the timestamp of this field or frame that is measured in seconds modulo 10. Table 6-24 defines the allowed range of values.

Table 6-24 – units_of_seconds values

Value	Meaning
0000-1001	number of seconds modulo 10
1010-1111	forbidden

tens_of_seconds – A 4-bit unsigned integer that is used to calculate the equivalent timestamp. It represents the portion of the timestamp of this field or frame that is measured in seconds divided by 10. Table 6-25 defines the allowed range of values.

Table 6-25 – tens_of_seconds values

Value	Meaning
0000-0101	number of seconds / 10
0110-1111	forbidden

units_of_minutes – A 4-bit integer that is used to calculate the equivalent timestamp. It represents the portion of the timestamp of this field or frame that is measured in minutes modulo 10. Table 6-26 defines the allowed range of values.

Table 6-26 – units_of_minutes values

Value	Meaning
0000-1001	number of minutes modulo 10
1010-1111	forbidden

tens_of_minutes – A 4-bit integer that is used to calculate the equivalent timestamp. It represents the portion of the timestamp of this field or frame that is measured in seconds divided by 10. Table 6-27 defines the allowed range of values.

Table 6-27 – tens_of_minutes values

Value	Meaning
0000-0101	number of minutes / 10
0110-1111	forbidden

units_of_hours – A 4-bit integer that is used to calculate the equivalent timestamp. It represents the portion of the timestamp of this field or frame that is measured in hours modulo 10. Table 6-28 defines the allowed range of values. It shall not exceed a value of "3" if tens_of_hours is equal to "2".

Table 6-28 – units_of_hours values

Value	Meaning
0000-1001	number of hours modulo 10
1010-1111	forbidden

tens_of_hours – A 4-bit integer that is used to calculate the equivalent timestamp. This field represents the portion of the timestamp of this field or frame that is measured in hours divided by 10. Table 6-29 defines the allowed range of values.

Table 6-29 – tens_of_hours values

Value	Meaning
0000-0010	number of hours / 10
0011-1111	forbidden

When counting_type is 0, an equivalent timestamp represented in 27 MHz system clock cycles is defined by the following formula:

equivalent_timestamp = (60 * (60 * (units_of_hours + 10 * tens_of_hours) +
(units_of_minutes + 10 * tens_of_minutes)) +
units_of_seconds + 10 * tens_of_seconds) * 27 000 000 + time_offset

When counting_type is 0, the values of the parameters within the timestamp shall be constrained by the encoder such that equivalent_timestamp shall not be less than 0 and shall not exceed 2 332 799 999 999.

When counting_type is not 0, an equivalent timestamp represented in 27 MHz system clock cycles is defined by the following formula:

equivalent_timestamp = (60 * (60 * (units_of_hours + 10 * tens_of_hours) +
(units_of_minutes + 10 * tens_of_minutes)) +
units_of_seconds + 10 * tens_of_seconds) * 27 000 000 +
(nframes * (nframes_multiplier * (1000 + nframes_conversion_code)) +
time_offset) * clock_divisor

When counting_type is not 0, the values of the parameters within the timecode shall be constrained by the encoder such that equivalent_timestamp shall not be less than 0.

Two identical equivalent_timestamps calculated from consecutive frames (or fields) without an intervening time_discontinuity indicate that both frames (or fields) were captured or created at the same instant in time.

6.3.21.3 Additional pan-scan parameters

Additional pan-scan parameters allow carriage of pan-scan information for more than one display type. For example, if the information encoded for a pan-scan process in the sequence header, sequence display extension, and picture display extension is used to define the parameters needed for representation on a 4:3 aspect ratio display, the additional pan-scan parameters can define the parameters needed for display on a 16:9 aspect ratio display.

aspect_ratio_information – A 4-bit integer value that is defined in 6.3.3 (sequence header). A value for aspect_ratio_information which is equal to the value specified in the sequence_header() shall not occur.

display_size_present – A 1-bit flag, when set to '1', indicates the presence of the display_horizontal_size_upper, display_horizontal_size_lower, display_vertical_size_upper, and display_vertical_size_lower parameters. When set to '0', the previous values of display_horizontal_size and display_vertical_size corresponding to the value of aspect_ratio_information shall be used. For a specific aspect ratio, this field should be set to '1' in the first picture header after any sequence_header(). Following a sequence_header(), the value of display_horizontal_size and display_vertical_size shall be the value defined in the sequence_display_extension().

display_horizontal_size_upper – The 6 most significant bits of display_horizontal_size.

display_horizontal_size_lower – The 8 least significant bits of display_horizontal_size.

display_horizontal_size – A 14-bit integer value defined in 6.3.6 (sequence display extension). For any specific value of aspect_ratio_information, the value of this parameter shall remain the same for the sequence.

display_vertical_size_upper – The 6 most significant bits of display_vertical_size.

display_vertical_size_lower – The 8 least significant bits of display_vertical_size.

display_vertical_size – A 14-bit integer value defined in 6.3.6 (sequence display extension). For any specific value of aspect_ratio_information, the value of this parameter shall remain the same for the sequence.

frame_centre_horizontal_offset_upper, frame_centre_horizontal_offset_lower – The 8 most significant and least significant bits, respectively, of frame_centre_horizontal_offset.

frame_centre_horizontal_offset – A 16-bit signed integer defined in 6.3.12 (picture display extension).

frame_centre_vertical_offset_upper, **frame_centre_vertical_offset_lower** – The 8 most significant and least significant bits, respectively, of frame_centre_vertical_offset.

frame_centre_vertical_offset – A 16-bit signed integer defined in 6.3.12 (picture display extension). Following a sequence_header(), the value zero shall be used for all frame centre offsets until a picture_display_extension() defines non-zero values.

number_of_frame_centre_offsets – An integer defined in 6.3.12. Following a sequence header, the value zero shall be used for all frame centre offsets until a picture display extension defines non-zero values.

6.3.21.4 Active region window

The active region window contains integers that define the rectangle in the reconstructed frame that is intended to be displayed. This window shall not be larger than the rectangle defined by the horizontal_size and vertical_size defined in 6.3.3. No more than one active_region_window for each picture shall be present in the bitstream. When a frame is coded as two field pictures, the active region window shall not be present in the second field picture.

top_left_x_upper, top_left_x_lower – The 8 most significant and least significant bits, respectively, of top_left_x.

top_left_x – A 16-bit integer that defines the sample number within a line of the luminance component in the reconstructed frame that, together with top_left_y, specifies the upper left corner of the active_region_window's rectangle.

top_left_y_upper, top_left_y_lower – The 8 most significant and least significant bits, respectively, of top_left_y.

top_left_y – A 16-bit integer that defines the line number for the luminance component in the reconstructed frame that, together with top_left_x, specifies the upper left corner of the active_region_window's rectangle.

active_region_horizontal_size_upper, active_region_horizontal_size_lower – The 8 most significant and least significant bits, respectively, of active_region_horizontal_size.

active_region_horizontal_size – A 16-bit integer that, together with active_region_vertical_size, defines a rectangle within the luminance component that may be considered the active region. If this rectangle is smaller than the encoded frame size, then the display process should display only that portion of the encoded frame. This value shall not be larger than the horizontal_size of the encoded frame. The value of '0' indicates that the size is unknown.

active_region_vertical_size_upper, active_region_vertical_size_lower – The 8 most significant and least significant bits, respectively, of active_region_vertical_size.

active_region_vertical_size – See the definition for active_region_horizontal_size. This value shall not be larger than the vertical_size of the encoded frame. The value of '0' indicates that the size is unknown.

In the case that a given frame does not have an active region window present in the bitstream, then the most recently decoded active region window shall be used. Following a sequence header, the active region window parameters active_region_horizontal_size and active_region_vertical_size shall be reset to the values of horizontal_size and vertical_size defined in the sequence header, and top_left_x and top_left_y shall be reset to 0.

6.3.21.5 Coded picture length

The coded picture length specifies the number of bytes included from the first byte immediately following the first slice_start_code of a picture to the first byte of the start code prefix immediately following the last macroblock of the picture. Not more than one coded picture length for each picture shall be present in the bitstream.

picture_byte_count_part_a, picture_byte_count_part_b, picture_byte_count_part_c, picture_byte_count_part_d – The 8 most significant, second most significant, third most significant, and least significant bits, respectively, of the picture_byte_count.

picture_byte_count – A 32-bit unsigned integer that indicates the number of bytes starting with the first byte of the first slice_start_code of the current picture and ending with the byte preceding the start code prefix immediately following the last macroblock of that picture. The value '0' is permitted. The value '0' indicates that the length of the picture is unknown.

7 The video decoding process

This clause specifies the decoding process that a decoder shall perform to reconstruct frames from the coded bitstream.

The IDCT function used in the decoding process for computation of f[y][x] may use any method of integral approximation of the mathematical integer-number IDCT defined in Annex A, provided the approximation conforms to the accuracy requirements specified in Annex A.

In 7.1 through 7.6 the simplest decoding process is specified in which no scalability features are used. Subclauses 7.7 to 7.11 specify the decoding process when scalable extensions are used. Subclause 7.12 defines the output of the decoding process.

Figure 7-1 is a diagram of the video decoding process without any scalability. The diagram is simplified for clarity.

NOTE – Throughout this Specification two dimensional arrays are represented as name[q][p] where 'q' is the index in the vertical dimension and 'p' the index in the horizontal dimension.

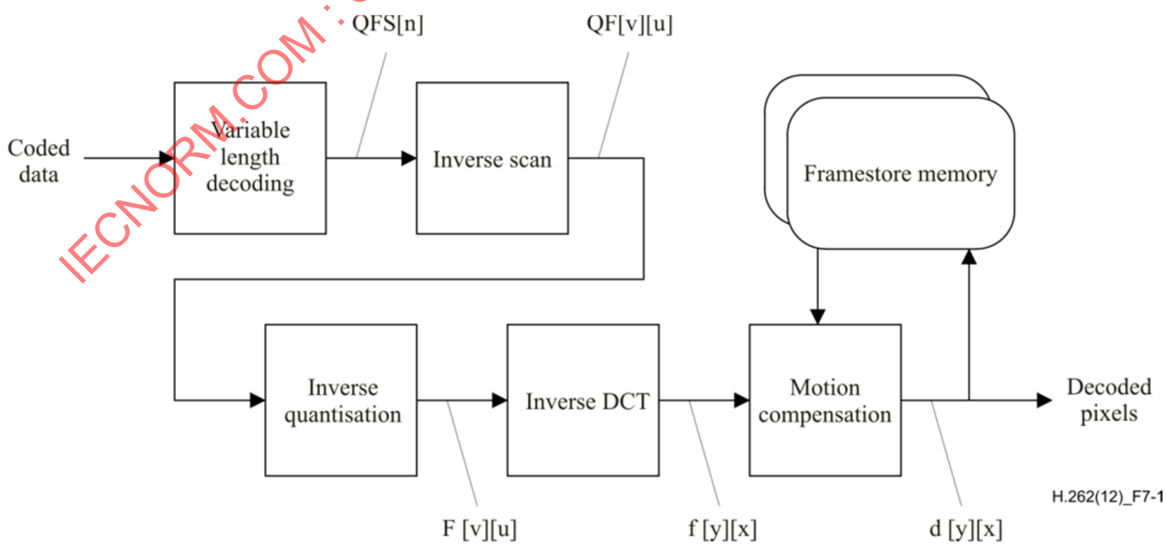


Figure 7-1 – Simplified video decoding process

7.1 Higher syntactic structures

The various parameters and flags in the bitstream for macroblock() and all syntactic structures above macroblock() shall be interpreted as indicated in clause 6. Many of these parameters and flags affect the decoding process described in the following subclauses. Once all of the macroblocks in a given picture have been processed, the entire picture will have been reconstructed.

Reconstructed fields shall be associated together in pairs to form reconstructed frames. (See "picture_structure" in 6.3.10.)

The sequence of reconstructed frames shall be re-ordered as described in 6.1.1.11.

If progressive_sequence == 1 the reconstructed frames shall be output from the decoding process at regular intervals of the frame period as shown in Figure 7-19.

If progressive_sequence == 0 the reconstructed frames shall be broken into a sequence of fields which shall be output from the decoding process at regular intervals of the field period as shown in Figure 7-20. In the case that a frame picture has repeat_first_field == 1 the first field of the frame shall be repeated after the second field. (See "repeat_first_field" in 6.3.10.)

7.2 Variable length decoding

Subclause 7.2.1 specifies the decoding process used for the DC coefficient (n = 0) in an intra-coded block. (n is the index of the coefficient in the appropriate zigzag scanning order.) Subclause 7.2.2 specifies the decoding process for all other coefficients, AC coefficients (n > 0) and DC coefficients in non-intra-coded blocks.

Let cc denote the colour component. It is related to the block number as specified in Table 7-1. Thus, cc is zero for the Y component, one for the Cb component and two for the Cr component.

Table 7-1 – Definition of cc, colour component index

Block Number	cc		
	4:2:0	4:2:2	4:4:4
0	0	0	0
1	0	0	0
2	0	0	0
3	0	0	0
4	1	1	1
5	2	2	2
6		1	1
7		2	2
8			1
9			2
10			1
11			2

7.2.1 DC coefficients in intra blocks

DC coefficients in blocks in intra macroblocks are encoded as a variable length code denoting dct_dc_size as defined in Tables B.12 and B.13. If dct_dc_size is not equal to zero, then this shall be followed by a fixed length code, dct_dc_differential, of dct_dc_size bits. A differential value is first recovered from the coded data which is added to a predictor in order to recover the final decoded coefficient.

If cc is zero then Table B.12 shall be used for dct_dc_size. If cc is non-zero, then Table B.13 shall be used for dct_dc_size.

Three predictors are maintained, one for each of the colour components, cc. Each time a DC coefficient in a block in an intra macroblock is decoded the predictor is added to the differential to recover the actual coefficient. Then the predictor shall be set to the value of the coefficient just decoded. At various times, as described below, the predictors shall be reset. The reset value is derived from the parameter intra_dc_precision as specified in Table 7-2.

Table 7-2 – Relation between intra_dc_precision and the predictor reset value

intra_dc_precision	Bits of precision	reset value
0	8	128
1	9	256
2	10	512
3	11	1024

The predictors shall be reset to the reset value at the following times:

- At the start of a slice.
- Whenever a non-intra macroblock is decoded.
- Whenever a macroblock is skipped, i.e. when macroblock_address_increment > 1.

The predictors are denoted dct_dc_pred[cc].

QFS[0] shall be calculated from dct_dc_size and dct_dc_differential by any process equivalent to:

```
if ( dct_dc_size == 0 ) {
      dct_diff = 0;
} else {
      half_range = 2 ^ ( dct_dc_size - 1 );
      if ( dct_dc_differential > = half_range )
            dct_diff = dct_dc_differential;
      else
            dct_diff = (dct_dc_differential + 1) - (2 * half_range);
}
QFS[0] = dct_dc_pred[cc] + dct_diff;
dct_dc_pred[cc] = QFS[0]
```

NOTE 1 – The symbol ^ denotes power (not XOR).

NOTE 2 – dct_diff and half_range are temporary variables which are not used elsewhere in this Specification.

It is a requirement of the bitstream that QFS[0] shall lie in the range:

$$0 \text{ to } ((2\hat{}(8 + \text{intra\_dc\_precision})) - 1)$$

7.2.2 Other coefficients

All coefficients with the exception of the DC intra coefficients shall be encoded using Tables B.14, B.15 and B.16.

In all cases a variable length code shall first be decoded using either Table B.14 or Table B.15. The decoded value of this code denotes one of three courses of action:

1) End of Block – In this case there are no more coefficients in the block in which case the remainder of the coefficients in the block (those for which no value has yet been decoded) shall be set to zero. This is denoted by "End of block" in the syntax specification of 6.2.6.

2) A "normal" coefficient in which a value of run and level is decoded followed by a single bit, s, giving the sign of the coefficient signed_level is computed from level and s as shown below. run coefficients shall be set to zero and the subsequent coefficient shall have the value signed_level.

```
if (s ==0)
            signed_level = level;
      else
            signed_level = (-level);
```

3) An "Escape" coded coefficient. In which the values of run and signed_level are fixed length coded as described in 7.2.2.3.

7.2.2.1 Table selection

Table 7-3 indicates which Table shall be used for decoding the DCT coefficients.

Table 7-3 – Selection of DCT coefficient VLC tables

intra_vlc_format	0	1
intra blocks (macroblock_intra = 1)	B.14	B.15
non-intra blocks (macroblock_intra = 0)	B.14	B.14

7.2.2.2 First coefficient of a non-intra block

In the case of the first coefficient of a non-intra block (a block in a non-intra macroblock) Table B.14 is modified as indicated by Notes 2 and 3 at the foot of that Table.

This modification only affects the entry that represents run = 0, level = ± 1. Since it is not possible to encode an End of block as the first coefficient of a block (the block would be "not coded" in this case) no possibility for ambiguity exists.

The positions in the syntax that use this modified Table are denoted by "First DCT coefficient" in the syntax specification of 6.2.6. The remainder of the coefficients are denoted by "Subsequent DCT coefficients".

NOTE – In the case that Table B.14 is used for an intra block, the first coefficient shall be coded as specified in 7.2.1. Table B.14 shall therefore not be modified as the first coefficient that uses Table B.14 is the second coefficient in the block.

7.2.2.3 Escape coding

Many possible combinations of run and level have no variable length code to represent them. In order to encode these statistically rare combinations an Escape coding method is used.

Table B.16 defines the escape coding method. The Escape VLC is followed by a 6-bit fixed length code giving "run". This is followed by a 12-bit fixed length code giving the values of "signed_level".

NOTE – Attention is drawn to the fact that the escape coding method used in this Specification is different to that used in ISO/IEC 11172-2.

7.2.2.4 Summary

To summarise 7.2.2, the variable length decoding process shall be equivalent to the following. At the start of this process n shall take the value zero for non-intra blocks and one for intra blocks.

```
eob_not_read = 1;
while ( eob_not_read )
{
    <decode VLC, decode Escape coded coefficient if required>
    if ( <decoded VLC indicates End of block> ) {
        eob_not_read = 0;
        while ( n < 64) {
            QFS[n] = 0;
            n = n + 1;
        }
    } else {
        for ( m = 0; m < run; m++ ) {
            QFS[n] = 0;
            n = n + 1;
        }
        QFS[n] = signed_level
        n = n + 1;
    }
}
```

NOTE – eob_not_read and m are temporary variables that are not used elsewhere in this Specification.

7.3 Inverse scan

Let the data at the output of the variable length decoder be denoted by QFS[n]. n is in the range 0 to 63.

This subclause specifies the way in which the one-dimensional data, QFS[n], is converted into a two-dimensional array of coefficients denoted by QF[v][u]. u and v both lie in the range 0 to 7.

Two scan patterns are defined. The scan that shall be used shall be determined by alternate_scan which is encoded in the picture coding extension.

Figure 7-2 defines scan[alternate_scan][v][u] for the case that alternate_scan is zero. Figure 7-3 defines scan[alternate_scan][v][u] for the case that alternate_scan is one.

The inverse scan shall be any process equivalent to the following:

```
for (v = 0; v < 8; v++)
    for (u = 0; u < 8; u++)
        QF[v][u] = QFS[scan[alternate_scan][v][u]]
```

NOTE – The scan patterns defined here are often referred to as "zigzag scanning order".

v \ u	0	1	2	3	4	5	6	7
0	0	1	5	6	14	15	27	28
1	2	4	7	13	16	26	29	42
2	3	8	12	17	25	30	41	43
3	9	11	18	24	31	40	44	53
4	10	19	23	32	39	45	52	54
5	20	22	33	38	46	51	55	60
6	21	34	37	47	50	56	59	61
7	35	36	48	49	57	58	62	63

Figure 7-2 – Definition of scan[0][v][u]

v \ u	0	1	2	3	4	5	6	7
0	0	4	6	20	22	36	38	52
1	1	5	7	21	23	37	39	53
2	2	8	19	24	34	40	50	54
3	3	9	18	25	35	41	51	55
4	10	17	26	30	42	46	56	60
5	11	16	27	31	43	47	57	61
6	12	15	28	32	44	48	58	62
7	13	14	29	33	45	49	59	63

Figure 7-3 – Definition of scan[1][v][u]

7.3.1 Inverse scan for matrix download

When the quantization matrices are downloaded they are encoded in the bitstream in a scan order that is converted into the two-dimensional matrix used in the inverse quantizer in an identical manner to that used for coefficients.

For matrix download the scan defined by Figure 7-2 (i.e. scan[0][v][u]) shall always be used.

Let W[w][v][u] denote the weighting matrix in the inverse quantizer (see 7.4.2.1), and W'[w][n] denote the matrix as it is encoded in the bitstream. The matrix download shall then be equivalent to the following:

```
for (v = 0; v < 8; v++)
    for (u = 0; u < 8; u++)
        W[w][v][u] = W'[w][scan[0][v][u]]
```

7.4 Inverse quantization

The two-dimensional array of coefficients, QF[v][u], is inverse quantized to produce the reconstructed DCT coefficients. This process is essentially a multiplication by the quantizer step size. The quantizer step size is modified by two mechanisms; a weighting matrix is used to modify the step size within a block and a scale factor is used in order that the step size can be modified at the cost of only a few bits (as compared to encoding an entire new weighting matrix).

Figure 7-4 illustrates the overall inverse quantization process. After the appropriate inverse quantization arithmetic the resulting coefficients, F''[v][u], are saturated to yield F'[v][u] and then a mismatch control operation is performed to give the final reconstructed DCT coefficients, F[v][u].

NOTE – Attention is drawn to the fact that the method of achieving mismatch control in this Specification is different to that employed by ISO/IEC 11172-2.

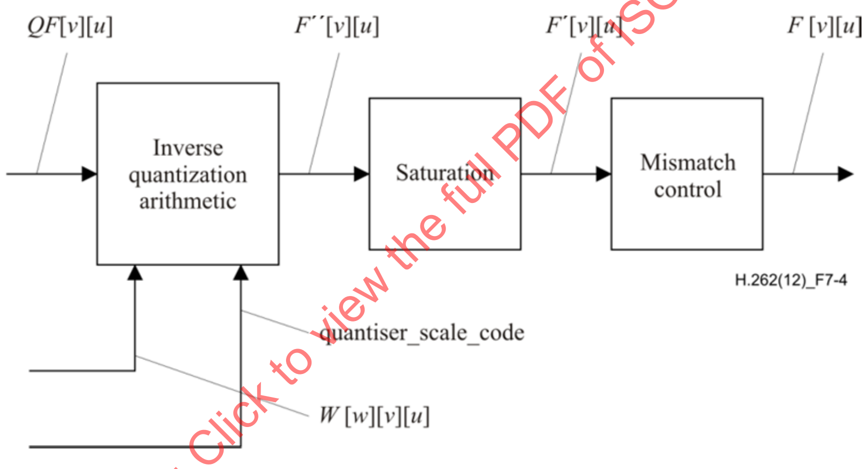


Figure 7-4 – Inverse quantization process

7.4.1 Intra DC coefficient

The DC coefficients of intra-coded blocks shall be inverse quantized in a different manner to all other coefficients.

In intra blocks F''[0][0] shall be obtained by multiplying QF[0][0] by a constant multiplier, intra_dc_mult, (constant in the sense that it is not modified by either the weighting matrix or the scale factor). The multiplier is related to the parameter intra_dc_precision that is encoded in the picture coding extension. Table 7-4 specifies the relation between intra_dc_precision and intra_dc_mult.

Thus; $F''[0][0] = \text{intra\_dc\_mult} \times QF[0][0]$

Table 7-4 – Relation between intra_dc_precision and intra_dc_mult

intra_dc_precision	Bits of precision	**intra_dc_mult**
0	8	8
1	9	4
2	10	2
3	11	1

7.4.2 Other coefficients

All coefficients other than the DC coefficient of an intra block shall be inverse quantized as specified in this subclause.

7.4.2.1 Weighting matrices

When 4:2:0 data is used, two weighting matrices are used. One shall be used for intra macroblocks and the other for non-intra macroblocks. When 4:2:2 or 4:4:4 data is used, four matrices are used allowing different matrices to be used for luminance and chrominance data. Each matrix has a default set of values which may be overwritten by down-loading a user defined matrix as explained in 6.2.3.2.

Let the weighting matrices be denoted by W[w][v][u] where w takes the values 0 to 3 indicating which of the matrices is being used. Table 7-5 summarises the rules governing the selection of w.

Table 7-5 – Selection of w

	4:2:0		4:2:2 and 4:4:4	
	Luminance (cc = 0)	Chrominance (cc ≠ 0)	Luminance (cc = 0)	Chrominance (cc ≠ 0)
intra blocks (macroblock_intra = 1)	0	0	0	2
non-intra blocks (macroblock_intra = 0)	1	1	1	3

7.4.2.2 Quantizer scale factor

The quantization scale factor is encoded as a 5-bit fixed length code, quantiser_scale_code. This indicates the appropriate quantiser_scale to apply in the inverse quantization arithmetic.

q_scale_type (encoded in the picture coding extension) indicates which of two mappings between quantiser_scale_code and quantiser_scale shall apply. Table 7-6 shows the two mappings between quantiser_scale_code and quantiser_scale.

7.4.2.3 Reconstruction formulae

The following equation specifies the arithmetic to reconstruct F''[v][u] from QF[v][u] (for all coefficients except intra DC coefficients).

$$F''[v][u] = ((2 \times QF[v][u] + k) \times W[w][v][u] \times quantiser\_scale / 32$$

where:

$$k = \begin{cases} 0 & \text{intra blocks} \\ \mathrm{Sign}(QF[v][u]) & \text{non-intra blocks} \end{cases}$$

NOTE – The above equation uses the "/" operator as defined in 4.1.

7.4.3 Saturation

The coefficients resulting from the inverse quantization arithmetic are saturated to lie in the range [–2048:+2047]. Thus:

$$F'[v][u] = \begin{cases} 2047 & F''[v][u] > 2047 \\ F''[v][u] & -2048 \le F''[v][u] \le 2047 \\ -2048 & F''[v][u] < -2048 \end{cases}$$

7.4.4 Mismatch control

Mismatch control shall be performed by any process equivalent to the following. Firstly all of the reconstructed, saturated coefficients, F'[v][u] in the block shall be summed. This value is then tested to determine whether it is odd or even. If the sum is even then a correction shall be made to just one coefficient; F[7][7]. Thus:

$$\text{sum} = \sum_{v=0}^{v<8} \sum_{u=0}^{u<8} F'[v][u]$$

$$F[v][u] = F'[v][u] \text{ for all u, v except } u = v = 7$$

$$F[7][7] = \begin{cases} F'[7][7] & \text{if sum is odd} \\ \left\{ \begin{array}{ll} F'[7][7] - 1 & \text{if } F'[7][7] \text{ is odd} \\ F'[7][7] + 1 & \text{if } F'[7][7] \text{ is even} \end{array} \right\} & \text{if sum is even} \end{cases}$$

NOTE 1 – It may be useful to note that the above correction for F[7][7] may simply be implemented by toggling the least significant bit of the two's complement representation of the coefficient. Also since only the "oddness" or "evenness" of the sum is of interest an exclusive OR (of just the least significant bit) may be used to calculate "sum".

NOTE 2 – Warning – Small non-zero inputs to the IDCT may result in all-zero output for some IDCT approximations that conform to the requirements specified in Annex A. If this occurs in an encoder, a mismatch may occur in decoders that use a different conforming IDCT approximation than the approximation used in modelling the decoding process within the encoder. An encoder should avoid this problem and may do so by checking the output of its own IDCT approximation. It should ensure that it never inserts any non-zero coefficients into the bitstream when the block in question reconstructs to zero through the encoder's own IDCT function approximation. If this action is not taken by the encoder, situations can arise where large and very visible mismatches between the state of the encoder and decoder occur.

Table 7-6 – Relation between quantiser_scale and quantiser_scale_code

quantiser_scale_code	quantiser_scale[q_scale_type]	
	q_scale_type = 0	q_scale_type = 1
0	(Forbidden)	
1	2	1
2	4	2
3	6	3
4	8	4
5	10	5
6	12	6
7	14	7
8	16	8
9	18	10
10	20	12
11	22	14
12	24	16
13	26	18
14	28	20
15	30	22
16	32	24
17	34	28
18	36	32
19	38	36
20	40	40
21	42	44
22	44	48
23	46	52
24	48	56
25	50	64
26	52	72
27	54	80
28	56	88
29	58	96
30	60	104
31	62	112

7.4.5 Summary

In summary the inverse quantization process is any process numerically equivalent to:

```
for (v = 0; v < 8;v++) {
    for (u = 0; u < 8;u++) {
        if ( (u==0) && (v==0) && (macroblock_intra) ) {
            F"[v][u] = intra_dc_mult * QF[v][u];
        } else {
            if ( macroblock_intra ) {
                F"[v][u] = ( QF[v][u] * W[w][v][u] * quantiser_scale * 2 ) / 32;
            } else {
                F"[v][u] = ( ( ( QF[v][u] * 2 ) + Sign(QF[v][u]) ) * W[w][v][u]
                                                        * quantiser_scale ) / 32;
            }
        }
    }
```

```
}

sum = 0;
    for (v = 0; v < 8;v++) {
        for (u = 0; u < 8;u++) {
            if ( F"[v][u] > 2047 ) {
                F'[v][u] = 2047;
            } else {
                if ( F"[v][u] < –2048 ) {
                    F'[v][u] = –2048;
                } else {
                    F'[v][u] = F"[v][u];
                }
            }
        sum = sum + F'[v][u];
        F[v][u] = F'[v][u];
        }
}

if ((sum & 1) == 0) {
    if ((F[7][7] & 1) ! = 0) {
        F[7][7] = F'[7][7] – 1;
    } else {
        F[7][7] = F'[7][7] + 1;
    }
}
```

7.5 Inverse DCT

Once the DCT coefficients, F[v][u] are reconstructed, an IDCT function that conforms to the accuracy requirements specified in Annex A shall be applied to obtain the inverse transformed values f[y][x], which are integers.

7.5.1 Non-coded blocks and skipped macroblocks

In a macroblock that is not skipped, if pattern_code[i] is one for a given block in the macroblock, then coefficient data is included in the bitstream for that block. This is decoded using as specified in the preceding clauses.

However, if pattern_code[i] is zero, or if the macroblock is skipped, then that block contains no coefficient data. The sample domain coefficients f[y][x] for such a block shall all take the value zero.

7.6 Motion compensation

The motion compensation process forms predictions from previously decoded pictures which are combined with the coefficient data (from the output of the IDCT) in order to recover the final decoded samples. Figure 7-5 shows a simplified diagram of this process.

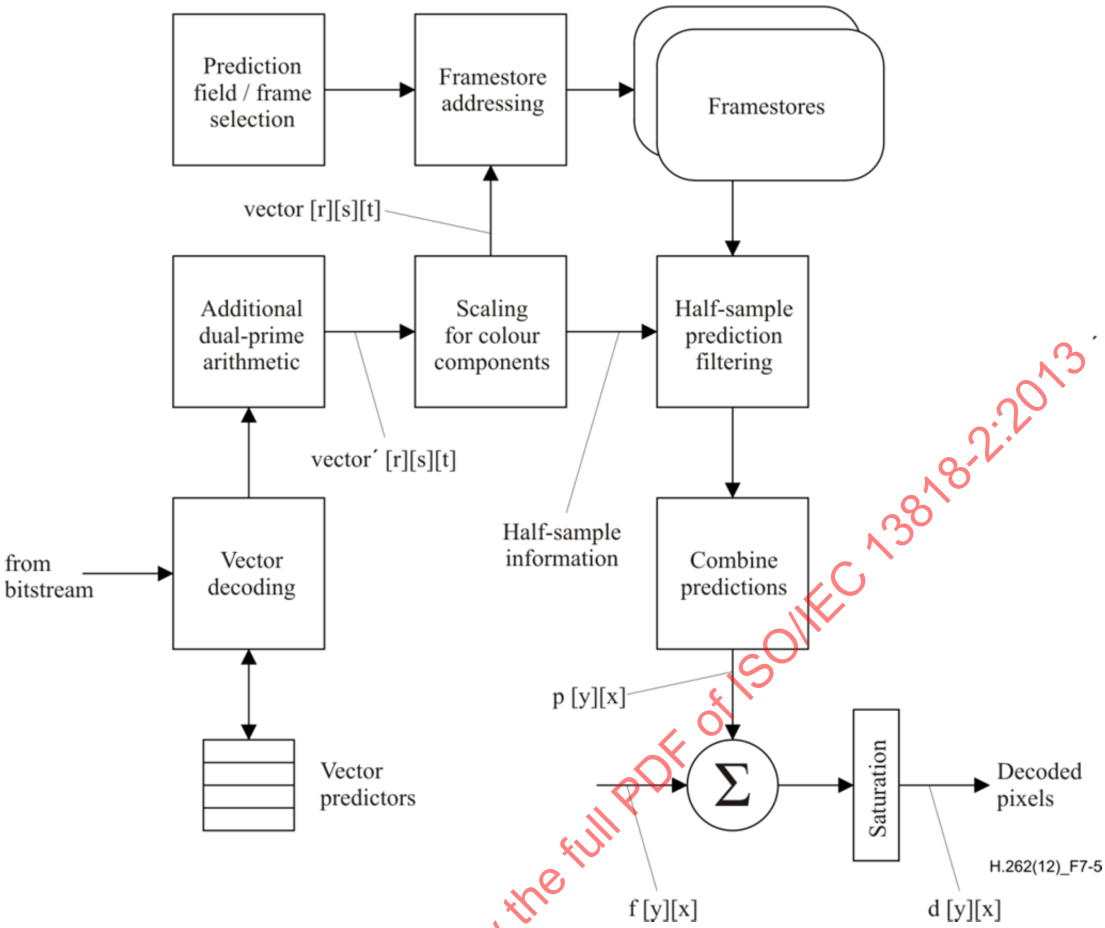


Figure 7-5 – Simplified motion compensation process

In general up to four separate predictions are formed for each block which are combined together to form the final prediction block p[y][x].

In the case of intra-coded macroblocks no prediction is formed so that p[y][x] will be zero. The saturation shown in Figure 7-5 is still required in order to remove negative values and values in excess of 255 (if present) from f[y][x]. Intra-coded macroblocks may carry motion vectors known as "concealment motion vectors". Despite this no prediction is formed in the normal course of events. This motion vector information is intended for use in the case that bitstream errors preclude the decoding of coefficient information. The way in which a decoder shall use this information is not specified. The only requirement for these motion vectors is that they shall have the correct syntax for motion vectors. A description of the way in which these motion vectors may be used can be found in 7.6.3.9.

For establishing a requirement of bitstream conformance, a prediction count increment value shall be derived for each macroblock in a P-picture as follows. If a macroblock in the current picture is skipped, its prediction count increment value shall be equal to 0. Otherwise, its prediction count increment value shall be equal to 1.

For establishing a requirement of bitstream conformance, for each macroblock in each I-picture and P-picture, a prediction count shall be derived as follows. If a macroblock is an intra-coded macroblock, its prediction count shall be equal to 0. Otherwise, if the current picture is a field picture and the most recently reconstructed reference picture is also a field picture or if the current picture is a frame picture and the most recently reconstructed reference picture is also a frame picture, the prediction count for a macroblock in the current picture shall be equal to the prediction count increment value plus the value of the prediction count for the macroblock in the most recently reconstructed reference picture that corresponds to the position of the selected macroblock in the current picture. Otherwise, the prediction count for a macroblock in the current picture shall be equal to the prediction count increment value plus the maximum of the values of the two prediction counts for the two macroblocks in the area of the most recently reconstructed reference picture that corresponds to the position of the selected macroblock in the current picture.

It is a requirement of bitstream conformance that for each macroblock in a P-picture, the value of the resulting prediction count shall be less than 132.

In the case where a block is not coded, either because the entire macroblock is skipped or the specific block is not coded there is no coefficient data. In this case f[y][x] is zero and the decoded samples are simply the prediction, p[y][x].

7.6.1 Prediction modes

There are two major classifications of the prediction mode:

- field prediction; and
- frame prediction.

In field prediction, predictions are made independently for each field by using data from one or more previously decoded fields. Frame prediction forms a prediction for the frame from one or more previously decoded frames. It must be understood that the fields and frames from which predictions are made may have been decoded, themselves, as either field pictures or frame pictures.

Within a field picture all predictions are field predictions. However, in a frame picture either field predictions or frame predictions may be used (selected on a macroblock-by macroblock basis).

In addition to the major classification of field or frame prediction two special prediction modes are used:

- 16 × 8 motion compensation – In which two motion vectors are used for each macroblock. The first motion vector is used for the upper 16 × 8 region, the second for the lower 16 × 8 region. In the case of a bidirectionally predicted macroblock a total of four motion vectors will be used since there will be two for the forward prediction and two for the backward prediction. In this Specification 16 × 8 motion compensation shall only be used with field pictures.
- Dual-prime – In which only one motion vector is encoded (in its full format) in the bitstream together with a small differential motion vector. In the case of field pictures two motion vectors are then derived from this information. These are used to form predictions from two reference fields (one top, one bottom) which are averaged to form the final prediction. In the case of frame pictures this process is repeated for the two fields so that a total of four field predictions are made. This mode shall only be used in P-pictures where there are no B-pictures between the predicted and reference fields or frames.

7.6.2 Prediction field and frame selection

The selection of which fields and frames shall be used to form predictions shall be made as detailed in this clause.

7.6.2.1 Field prediction

In P-pictures, the two reference fields from which predictions shall made are the most recently decoded reference top field and the most recently decoded reference bottom field. The simplest case illustrated in Figure 7-6 shall be used when predicting the first picture of a coded frame or when using field prediction within a frame picture. In these cases the two reference fields are part of the same reconstructed frame.

NOTE 1 – The reference fields may themselves have been reconstructed from two field-pictures or a single frame picture.

NOTE 2 – In the case of predicting a field picture, the field being predicted may be either the top field or the bottom field.

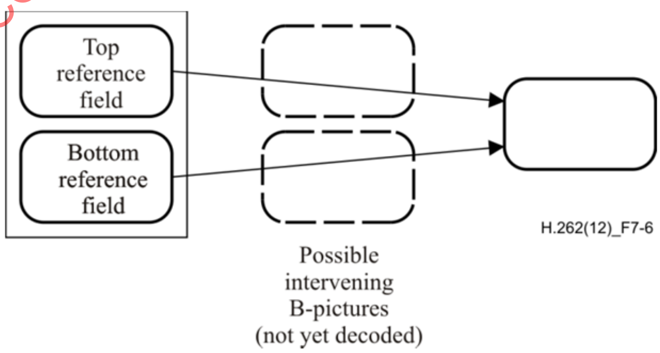


Figure 7-6 – Prediction of the first field or prediction in a frame picture

The case when predicting the second field picture of a coded frame is more complicated because the two most recently decoded reference fields shall be used, and in this case, the most recent reference field was obtained from decoding the first field picture of the coded frame. Figure 7-7 illustrates the situation when this second picture is the bottom field. Figure 7-8 illustrates the situation when this second picture is the top field.

NOTE 3 – The earlier reference field may itself have been reconstructed by decoding a field picture or a frame picture.

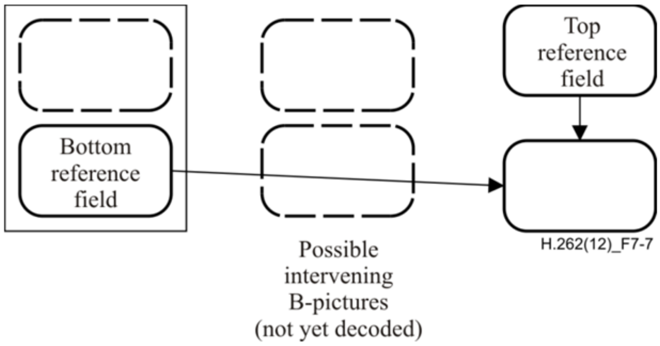


Figure 7-7 – Prediction of the second field-picture when it is the bottom field

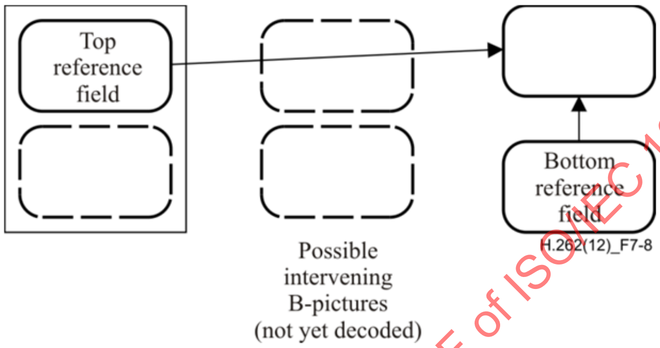


Figure 7-8 – Prediction of the second field-picture when it is the top field

Field prediction in B-pictures shall be made from the two fields of the two most recently reconstructed reference frames. Figure 7-9 illustrates this situation.

NOTE 4 – The reference frames may themselves have been reconstructed from two coded field-pictures or a single coded frame picture.

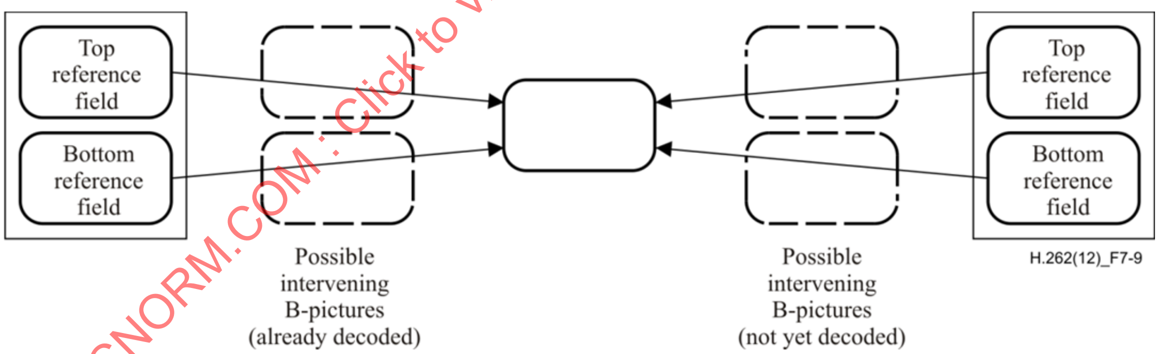


Figure 7-9 – Field-prediction of B-field pictures or B-frame pictures

7.6.2.2 Frame prediction

In P-pictures prediction shall be made from the most recently reconstructed reference frame. This is illustrated in Figure 7-10.

NOTE 1 – The reference frame may itself have been coded as two field pictures or a single frame picture.

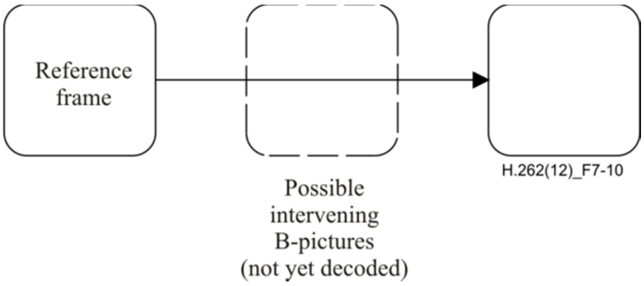


Figure 7-10 – Frame prediction for I-pictures and P-pictures

Similarly frame prediction in B-pictures shall be made from the two most recently reconstructed reference frames as illustrated in Figure 7-11.

NOTE 2 – The reference frames themselves may each have been coded as either two field pictures or a single frame picture.

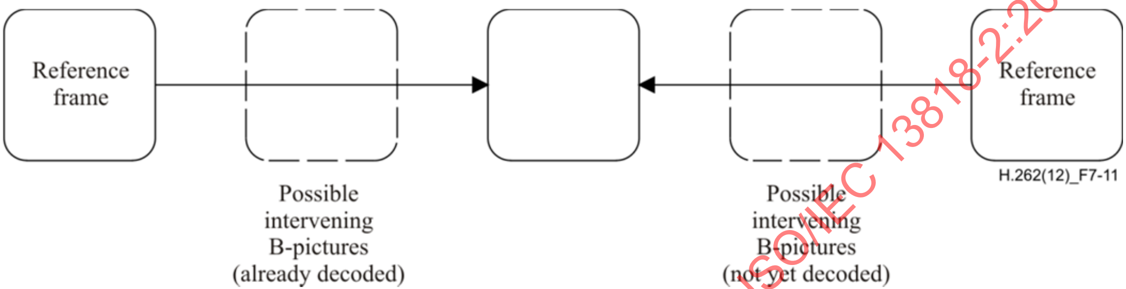


Figure 7-11 – Frame-prediction for B-pictures

7.6.3 Motion vectors

Motion vectors are coded differentially with respect to previously decoded motion vectors in order to reduce the number of bits required to represent them. In order to decode the motion vectors the decoder shall maintain four motion vector predictors (each with a horizontal and vertical component) denoted PMV[r][s][t]. For each prediction, a motion vector, vector'[r][s][t] is first derived. This is then scaled depending on the sampling structure (4:2:0, 4:2:2 or 4:4:4) to give a motion vector, vector[r][s][t], for each colour component. The meanings associated with the dimensions in this array are defined in Table 7-7.

Table 7-7 – Meaning of indices in PMV[r][s][t], vector[r][s][t] and vector'[r][s][t]

	0	1
r	First motion vector in Macroblock	Second motion vector in Macroblock
s	Forward motion Vector	Backwards motion Vector
t	Horizontal Component	Vertical Component
NOTE – r also takes the values 2 and 3 for derived motion vectors used with dual-prime prediction. Since these motion vectors are derived they do not themselves have motion vector predictors.		

7.6.3.1 Decoding the motion vectors

Each motion vector component, vector'[r][s][t], shall be calculated by any process that is equivalent to the following one. Note that the motion vector predictors shall also be updated by this process.

```
r_size = f_code[s][t] – 1
f = 1 << r_size
high = ( 16 * f ) – 1;
low = ( (–16) * f );
range = ( 32 * f );

if ( (f == 1) || (motion_code[r][s][t] == 0) )
    delta = motion_code[r][s][t] ;
else {
    delta = ( ( Abs(motion_code[r][s][t]) – 1 ) * f ) + motion_residual[r][s][t] + 1;
    if (motion_code[r][s][t] < 0)
        delta = – delta;
}

prediction = PMV[r][s][t];
if ( (mv_format == "field") && (t==1) && (picture_structure == "Frame picture") )
    prediction = PMV[r][s][t] DIV 2;

vector'[r][s][t] = prediction + delta;
if (vector'[r][s][t] < low )
    vector'[r][s][t] = vector'[r][s][t] + range;
if (vector'[r][s][t] > high)
    vector'[r][s][t] = vector'[r][s][t] – range;


if ( (mv_format == "field") && (t == 1) && (picture_structure == "Frame picture") )
    PMV[r][s][t] = vector'[r][s][t] * 2;
else
    PMV[r][s][t] = vector'[r][s][t];
```

The parameters in the bitstream shall be such that the reconstructed differential motion vector, delta, shall lie in the range [low:high]. In addition the reconstructed motion vector, vector'[r][s][t], and the updated value of the motion vector predictor PMV[r][s][t], shall also lie in the range [low : high].

r_size, f, delta, high, low and range are temporary variables that are not used in the remainder of this Specification.

motion_code[r][s][t] and motion_residual[r][s][t] are fields recovered from the bitstream. mv_format is recovered from the bitstream using Tables 6-17 and 6-18.

r, s and t specify the particular motion vector component being processed as identified in Table 7-7.

vector'[r][s][t] is the final reconstructed motion vector for the luminance component of the macroblock.

The vector'[r][s][t] value considered in this subclause is the one obtained from the pseudo code above. In case of dual-prime, this restriction that vector'[r][s][t] shall be in the range [low:high] does not apply to the scaled motion vectors vector'[2:3][0][0:1] defined in 7.6.3.6. Other restrictions on motion vectors, including scaled dual-prime motion vectors are specified in 7.6.3.8 and 8.3.

7.6.3.2 Motion vector restrictions

In frame pictures, the vertical component of field motion vectors shall be restricted so that they only cover half the range that is supported by the f_code that relates to those motion vectors. This restriction ensures that the motion vector predictors will always have values that are appropriate for decoding subsequent frame motion vectors. Table 7-8 summarises the size of motion vectors that may be coded as a function of f_code.

7.6.3.3 Updating motion vector predictors

Once all of the motion vectors present in the macroblock have been decoded using the process defined in the previous clause it is sometimes necessary to update other motion vector predictors. This is because in some prediction modes fewer than the maximum possible number of motion vectors are used. The remainder of the predictors that might be used in the picture must retain "sensible" values in case they are subsequently used.

Table 7-8 – Allowable motion vector range as a function of f_code[s][t]

f_code[s][t]	Vertical components (t == 1) of field vectors in frame pictures	All other cases
0	(Forbidden)	
1	[–4: +3.5]	[–8: +7.5]
2	[–8: +7.5]	[–16: +15.5]
3	[–16: +15.5]	[–32: +31.5]
4	[–32: +31.5]	[–64: +63.5]
5	[–64: +63.5]	[–128: +127.5]
6	[–128: +127.5]	[–256: +255.5]
7	[–256: +255.5]	[–512: +511.5]
8	[–512: +511.5]	[–1024: +1023.5]
9	[–1024: +1023.5]	[–2048: +2047.5]
10-14	(Reserved)	
15	(Used when a particular f_code[s][t] will not be used)	

The motion vector predictors shall be updated as specified in Table 7-9 and 7-10. The rules for updating motion vector predictors in the case of skipped macroblocks are specified in 7.6.6.

NOTE – It is possible for an implementation to optimise the updating (and resetting) of motion vector predictors depending on the picture type. For example in a P-picture the predictors for backwards motion vectors are unused and need not be maintained.

Table 7-9 – Updating of motion vector predictors in frame pictures

frame_motion_-type	**macroblock_motion_-**		**macroblock_-intra**	Predictors to Update
	forward	**backward**		
Frame-based[a)]	–	–	1	PMV[1][0][1:0] = PMV[0][0][1:0][b)]
Frame-based	1	1	0	PMV[1][0][1:0] = PMV[0][0][1:0] PMV[1][1][1:0] = PMV[0][1][1:0]
Frame-based	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0]
Frame-based	0	1	0	PMV[1][1][1:0] = PMV[0][1][1:0]
Frame-based[a)]	0	0	0	PMV[r][s][t] = 0[c)]
Field-based	1	1	0	(None)
Field-based	1	0	0	(None)
Field-based	0	1	0	(None)
Dual prime	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) If **concealment_motion_vectors** is zero then PMV[r][s][t] is set to zero (for all r, s and t).

c) (Only occurs in P-picture) PMV[r][s][t] is set to zero (for all r, s and t). See 7.6.3.4.

NOTE – PMV[r][s][1:0] = PMV[u][v][1:0] means that:

PMV[r][s][1] = PMV[u][v][1] and PMV[r][s][0] = PMV[u][v][0]

Table 7-10 – Updating of motion vector predictors in field pictures

frame_motion_-type	macroblock_motion_- forward	macroblock_motion_- backward	macroblock_-intra	Predictors to Update
Field-based[a)]	–	–	1	PMV[1][0][1:0] = PMV[0][0][1:0][b)]
Field-based	1	1	0	PMV[1][0][1:0] = PMV[0][0][1:0] PMV[1][1][1:0] = PMV[0][1][1:0]
Field-based	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0]
Field-based	0	1	0	PMV[1][1][1:0] = PMV[0][1][1:0]
Field-based[a)]	0	0	0	PMV[r][s][t] = 0[c)]
16 × 8 MC	1	1	0	(None)
16 × 8 MC	1	0	0	(None)
16 × 8 MC	0	1	0	(None)
Dual prime	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) If **concealment_motion_vectors** is zero then PMV[r][s][t] is set to zero (for all r, s and t).

c) (Only occurs in P-picture) PMV[r][s][t] is set to zero (for all r, s and t). See 7.6.3.4.

NOTE – PMV[r][s][1:0] = PMV[u][v][1:0] means that:

PMV[r][s][1] = PMV[u][v][1] and PMV[r][s][0] = PMV[u][v][0]

7.6.3.4 Resetting motion vector predictors

All motion vector predictors shall be reset to zero in the following cases:

- At the start of each slice.
- Whenever an intra macroblock is decoded which has no concealment motion vectors.
- In a P-picture when a non-intra macroblock is decoded in which macroblock_motion_forward is zero.
- In a P-picture when a macroblock is skipped.

7.6.3.5 Prediction in P-pictures

In P-pictures, in the case that macroblock_motion_forward is zero and macroblock_intra is also zero no motion vectors are encoded for the macroblock yet a prediction must be formed. If this occurs in a P-field picture the following apply;

- the prediction type shall be "Field-based";
- the (field) motion vector shall be zero (0;0);
- the motion vector predictors shall be reset to zero;
- predictions shall be made from the field of the same parity as the field being predicted.

If this occurs in a P-frame picture the following apply:

- the prediction type shall be "Frame-based";
- the (frame) motion vector shall be zero (0;0);
- the motion vector predictors shall be reset to zero.

In the case that a P-field picture is used as the second field of a frame in which the first field is an I-field picture a series of semantic restrictions apply. These ensure that prediction is only made from the I field picture. These restrictions are:

- There shall be no macroblocks that are coded with macroblock_motion_forward zero and macroblock_intra zero.
- Dual prime prediction shall not be used.
- Field prediction in which **motion_vertical_field_select** indicates the same parity as the field being predicted shall not be used.
- There shall be no skipped macroblocks.

7.6.3.6 Dual prime additional arithmetic

In dual prime prediction one field motion vector (vector'[0][0][1:0]) will have been decoded by the process already described. This represents the motion vector used to form predictions from the reference field (or reference fields in a frame picture) of the same parity as the prediction being formed. Here the word "parity" is used to differentiate the two fields. The top field has parity zero, the bottom field has parity one.

In order to form a motion vector for the opposite parity (vector'[r][0][1:0]) the existing motion vector is scaled to reflect the different temporal distance between the fields. A correction is made to the vertical component (to reflect the vertical shift between the lines of top field and bottom field) and then a small differential motion vector is added. This process is illustrated in Figure 7-12 which shows the situation for a frame picture.

dmvector[0] is the horizontal component of the differential motion vector and dmvector[1] the vertical component. The two components of the differential motion vector shall be decoded directly using Table B.11 and shall take only one of the values –1, 0, + 1.

m[parity_ref][parity_pred] is the field distance between the predicted field and the reference field as defined in Table 7-11. "parity_ref" is the parity of the reference field for which the new motion vector is being computed. "parity_pred" is the parity of the field that shall be predicted.

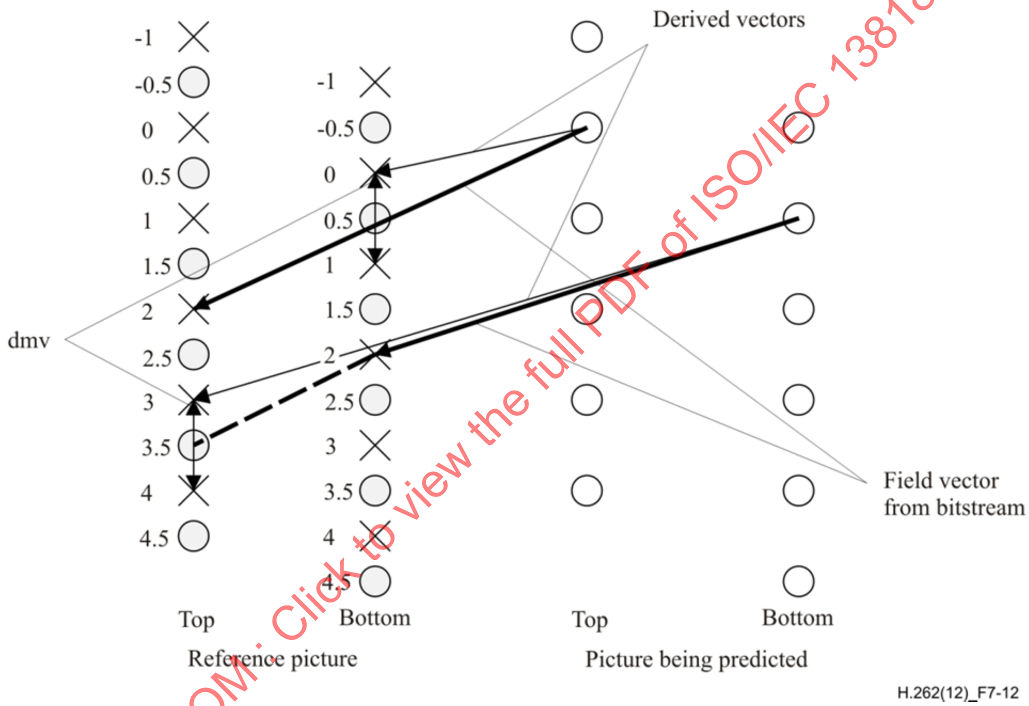


Figure 7-12 – Scaling of motion vectors for dual prime prediction

Table 7-11 – Definition of m[parity_ref][parity_pred]

picture_structure	top_field_first	m[parity_ref][parity_pred]	
		m[1][0]	m[0][1]
11 (Frame)	1	1	3
11 (Frame)	0	3	1
01 (Top Field)	–	1	–
10 (Bottom Field)	–	–	1

e[parity_ref][parity_pred] is the adjustment necessary to reflect the vertical shift between the lines of top field and bottom field as defined in Table 7-12.

Table 7-12 – Definition of e[parity_ref][parity_pred]

parity_ref	parity_pred	e[parity_ref][parity_pred]
0	1	+1
1	0	–1

The motion vector (or motion vectors) used for predictions of opposite parity shall be computed as follows:

vector'[r][0][0] = ((vector'[0][0][0] * m[parity_ref][parity_pred])//2) + dmvector[0];

vector'[r][0][1] = ((vector'[0][0][1] * m[parity_ref][parity_pred])//2)

+ e[parity_ref][parity_pred] + dmvector[1];

In the case of field pictures only one such motion vector is required and here r = 2. Thus, the (encoded) motion vector used for the same parity prediction is vector'[0][0][1:0] and the motion vector used for the opposite parity prediction is vector'[2][0][1:0].

In the case of frame pictures two such motion vectors are required. Both fields use the encoded motion vector (vector'[0][0][1:0]) for predictions of the same parity. The top field shall use vector'[2][0][1:0] for opposite parity prediction and the bottom field shall use vector'[3][0][1:0] for opposite parity prediction.

7.6.3.7 Motion vectors for chrominance components

The motion vectors calculated in the previous clauses refer to the luminance component where:

vector[r][s][t] = vector'[r][s][t] (for all r, s and t)

For each of the two chrominance components the motion vectors shall be scaled as follows:

4:2:0 Both the horizontal and vertical components of the motion vector are scaled by dividing by two:

vector[r][s][0] = vector'[r][s][0] / 2;

vector[r][s][1] = vector'[r][s][1] / 2;

4:2:2 The horizontal component of the motion vector is scaled by dividing by two, the vertical component is not altered:

vector[r][s][0] = vector'[r][s][0] / 2;

vector[r][s][1] = vector'[r][s][1];

4:4:4 The motion vector is unmodified:

vector[r][s][0] = vector'[r][s][0];

vector[r][s][1] = vector'[r][s][1];

7.6.3.8 Semantic restrictions concerning predictions

It is a requirement on the bitstream that it shall only demand of a decoder that predictions shall be made from slices actually encoded in a reference frame or reference field. This rule applies even for skipped macroblocks and macroblocks in P-pictures in which a zero motion vector is assumed (as explained in 7.6.3.5).

NOTE – As explained in 6.1.2 it is, in general, not necessary for the slices to cover the entire picture. However, in many defined levels of defined profiles the "restricted slice structure" is used in which case the slices do cover the entire picture. In this case the semantic rule may be more simply stated: "it is a restriction on the bitstream that reconstructed motion vectors shall not refer to samples outside the boundary of the coded picture."

7.6.3.9 Concealment motion vectors

Concealment motion vectors are motion vectors that may be carried by intra macroblocks for the purpose of concealing errors if data errors preclude decoding the coefficient data. A concealment motion vector shall be present for all intra macroblocks if (and only if) concealment_motion_vectors (in the picture_coding_extension()) has the value one.

In the normal course of events no prediction shall be formed for such macroblocks (as would be expected since macroblock_intra = 1). This Specification does not specify how error recovery shall be performed. However it is a recommendation that concealment motion vectors are suitable for use by a decoder that performs concealment by forming predictions as if field_motion_type and frame_motion_type (from which the prediction type is derived) have the following values:

- In a field picture: field_motion_type = "Field-based";

- In a frame picture: frame_motion_type = "Frame-based".

NOTE – If concealment is used in an I-picture then the decoder should perform prediction in a similar way to a P-picture.

Concealment motion vectors are intended for use in the case that a data error results in information being lost. There is therefore little point in encoding the concealment motion vector in the macroblock for which it is intended to be used since if the data error results in the need for error recovery it is very likely that the concealment motion vector itself would be lost or corrupted. As a result the following semantic rules are appropriate:

- For all macroblocks except those in the bottom row of macroblocks concealment motion vectors should be appropriate for use in the macroblock that lies vertically below the macroblock in which the motion vector occurs.
- When the motion vector is used with respect to the macroblock identified in the previous rule a decoder must assume that the motion vector may refer to samples outside of the slices encoded in the reference frame or reference field.
- For all macroblocks in the bottom row of macroblocks the reconstructed concealment motion vectors will not be used. Therefore the motion vector (0;0) may be used to reduce unnecessary overhead.

7.6.4 Forming predictions

Predictions are formed by reading prediction samples from the reference fields or frames. A given sample is predicted by reading the corresponding sample in the reference field or frame offset by the motion vector.

A positive value of the horizontal component of a motion vector indicates that the prediction is made from samples (in the reference field/frame) that lie to the right of the samples being predicted.

A positive value of the vertical component of a motion vector indicates that the prediction is made from samples (in the reference field/frame) that lie below the samples being predicted.

All motion vectors are specified to an accuracy of one half sample. Thus, if a component of the motion vector is odd, the samples will be read from mid-way between the actual samples in the reference field/frame. These half-samples are calculated by simple linear interpolation from the actual samples.

In the case of field-based predictions it is necessary to determine which of the two available fields to use to form the prediction. In the case of dual-prime this is specified in that a motion vector is derived for both of the fields and a prediction is formed from each. In the case of field-based prediction and 16 × 8 MC an additional bit, motion_vertical_field_select, is encoded to indicate which field to use.

If motion_vertical_field_select is zero, then the prediction is taken from the top reference field.

If motion_vertical_field_select is one, then the prediction is taken from the bottom reference field.

For each prediction block the integer sample motion vectors int_vec[t] and the half sample flags half_flag[t] shall be formed as follows;

```
for (t = 0; t< 2; t++) {
    int_vec[t] = vector[r][s][t] DIV 2;
    if ((vector[r][s][t] - (2 * int_vec[t]) != 0)
        half_flag[t] = 1;
    else
        half_flag[t] = 0;
}
```

Then for each sample in the prediction block the samples are read and the half sample prediction applied as follows;

```
if ( (! half_flag[0] )&& (! half_flag[1]) )
    pel_pred[y][x] = pel_ref[y + int_vec[1]][x + int_vec[0]];

if ( (! half_flag[0] )&& half_flag[1] )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                        pel_ref[y + int_vec[1]+1][x + int_vec[0]] ) // 2;
if ( half_flag[0]&& (! half_flag[1]) )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                        pel_ref[y + int_vec[1]][x + int_vec[0]+1] ) // 2;
if ( half_flag[0]&& half_flag[1] )
    pel_pred[y][x] = ( pel_ref[y + int_vec[1]][x + int_vec[0]] +
                        pel_ref[y + int_vec[1]][x + int_vec[0]+1] +
```

pel_ref[y + int_vec[1]+1][x + int_vec[0]] +
pel_ref[y + int_vec[1]+1][x + int_vec[0]+1]) // 4;

where pel_pred[y][x] is the prediction sample being formed and pel_ref[y][x] are samples in the reference field or frame.

7.6.5 Motion vector selection

Table 7-13 shows the prediction modes used in field pictures and Table 7-14 shows the predictions used in frame pictures. In each table the motion vectors that are present in the bitstream are listed in the order in which they appear in the bitstream.

Table 7-13 – Predictions and motion vectors in field pictures

field_ motion_ type	**macroblock_motion_-**		**macro- block_- intra**	Motion vector	Prediction formed for
	forward	**backward**			
Field-based[a)]	–	–	1	vector'[0][0][1:0][b)]	None (motion vector is for concealment)
Field-based	1	1	0	vector'[0][0][1:0] vector'[0][1][1:0]	Whole field, forward Whole field, backward
Field-based	1	0	0	vector'[0][0][1:0]	Whole field, forward
Field-based	0	1	0	vector'[0][1][1:0]	Whole field, backward
Field-based[a)]	0	0	0	vector'[0][0][1:0][c) d)]	Whole field, forward
16×8 MC	1	1	0	vector'[0][0][1:0] vector'[1][0][1:0] vector'[0][1][1:0] vector'[1][1][1:0]	Upper 16×8 field, forward Lower 16×8 field, forward Upper 16×8 field, backward Lower 16×8 field, backward
16×8 MC	1	0	0	vector'[0][0][1:0] vector'[1][0][1:0]	Upper 16×8 field, forward Lower 16×8 field, forward
16×8 MC	0	1	0	vector'[0][1][1:0] vector'[1][1][1:0]	Upper 16×8 field, backward Lower 16×8 field, backward
Dual prime	1	0	0	vector'[0][0][1:0] vector'[2][0][1:0][c) e)]	Whole field, from same parity, forward Whole field, from opposite parity, forward

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from vector'[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

Table 7-14 – Predictions and motion vectors in frame pictures

frame_-motion_-type	macroblock_motion_- forward	macroblock_motion_- backward	macro-block_-intra	Motion vector	Prediction formed for
Frame-based[a)]	–	–	1	vector'[0][0][1:0][b)]	None (motion vector is for concealment)
Frame-based	1	1	0	vector'[0][0][1:0] vector'[0][1][1:0]	Frame, forward Frame, backward
Frame-based	1	0	0	vector'[0][0][1:0]	Frame, forward
Frame-based	0	1	0	vector'[0][1][1:0]	Frame, backward
Frame-based[a)]	0	0	0	vector'[0][0][1:0][c) d)]	Frame, forward
Field-based	1	1	0	vector'[0][0][1:0] vector'[1][0][1:0] vector'[0][1][1:0] vector'[1][1][1:0]	Top field, forward Bottom field, forward Top field, backward Bottom field, backward
Field-based	1	0	0	vector'[0][0][1:0] vector'[1][0][1:0]	Top field, forward Bottom field, forward
Field-based	0	1	0	vector'[0][1][1:0] vector'[1][1][1:0]	Top field, backward Bottom field, backward
Dual prime	1	0	0	vector'[0][0][1:0] vector'[0][0][1:0] vector'[2][0][1:0][c) e)] vector'[3][0][1:0][c) e)]	Top field, from same parity, forward Bottom field, from same parity, forward Top field, from opposite parity, forward Bottom field, from opposite parity, forward

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from vector'[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

7.6.6 Skipped macroblocks

A skipped macroblock is a macroblock for which no data is encoded, that is part of a coded slice. Except at the start of a slice, if the number (macroblock_address - previous_macroblock_address - 1) is larger than zero, then this number indicates the number of macroblocks that have been skipped. The decoder shall form a prediction for skipped macroblocks which shall then be used as the final decoded sample values.

The handling of skipped macroblocks is different between P-pictures and B-pictures. In addition, the process differs between field pictures and frame pictures.

There shall be no skipped macroblocks in I-pictures except when either:

– picture_spatial_scalable_extension() follows the picture_header() of the current picture; or

– sequence_scalable_extension() is present in the bitstream and scalable_mode = "SNR scalability".

7.6.6.1 P field picture

- the prediction shall be made as if field_motion_type is "Field-based";
- the prediction shall be made from the field of the same parity as the field being predicted;
- motion vector predictors shall be reset to zero;
- the motion vector shall be zero.

7.6.6.2 P frame picture

- the prediction shall be made as if frame_motion_type is "Frame-based";
- motion vector predictors shall be reset to zero;
- the motion vector shall be zero.

7.6.6.3 B field picture

- the prediction shall be made as if field_motion_type is "Field-based";
- the prediction shall be made from the field of the same parity as the field being predicted;
- the direction of the prediction forward/backward/bi-directional shall be the same as the previous macroblock;
- motion vector predictors are unaffected;
- the motion vectors are taken from the appropriate motion vector predictors. Scaling of the motion vectors for colour components shall be performed as described in 7.6.3.7.

7.6.6.4 B frame picture

- the prediction shall be made as if frame_motion_type is "Frame-based";
- the direction of the prediction forward/backward/bi-directional shall be the same as the previous macroblock;
- motion vector predictors are unaffected;
- the motion vectors are taken directly from the appropriate motion vector predictors. Scaling of the motion vectors for colour components shall be performed as described in 7.6.3.7.

7.6.7 Combining predictions

The final stage is to combine the various predictions together in order to form the final prediction blocks.

It is also necessary to organize the data into blocks that are either field organized or frame organized in order to be added directly to the decoded coefficients.

The transform data is either field organized or frame organized as specified by dct_type.

7.6.7.1 Simple frame predictions

In the case of simple frame predictions the only further processing that may be required is to average forward and backward predictions in B-pictures. If pel_pred_forward[y][x] is the forwards prediction sample and pel_pred_backward[y][x] is the corresponding backward prediction, then the final prediction sample shall be formed as:

$$pel\_pred[y][x] = (pel\_pred\_forward[y][x] + pel\_pred\_backward[y][x])//2$$

The predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.7.2 Simple field predictions

In the case of simple field predictions (i.e. neither 16×8 or dual prime) the only further processing that may be required is to average forward and backward predictions in B-pictures. This shall be performed as specified for "Frame predictions" in the previous subclause.

In the case of simple field prediction in a frame picture the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats for each field shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

In the case of simple field prediction in a field picture the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats for each field shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.7.3 16×8 Motion compensation

In this prediction mode separate predictions are formed for the upper 16×8 region of the macroblock and the lower 16×8 region of the macroblock.

The predictions for chrominance components, for each 16×8 region, of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

7.6.7.4 Dual prime

In dual prime mode two predictions are formed for each field in an analogous manner to the backward and forward predictions in B-pictures. If pel_pred_same_parity[y][x] is the prediction sample from the same parity field and pel_pred_opposite_parity[y][x] is the corresponding sample from the opposite parity field then the final prediction sample shall be formed as:

pel_pred[y][x] = (pel_pred_same_parity[y][x] + pel_pred_opposite_parity[y][x])//2;

In the case of dual prime prediction in a frame picture, the predictions for chrominance components of each field of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 4 lines, 8 samples by 8 lines and 16 samples by 8 lines respectively.

In the case of dual prime prediction in a field picture, the predictions for chrominance components of 4:2:0, 4:2:2 and 4:4:4 formats shall be of size 8 samples by 8 lines, 8 samples by 16 lines and 16 samples by 16 lines respectively.

7.6.8 Adding prediction and coefficient data

The prediction blocks have been formed and reorganized into blocks of prediction samples p[y][x] which match the field/frame structure used by the transform data blocks.

The transform data f[y][x] shall be added to the prediction data and saturated to form the final decoded samples d[y][x] as follows:

```
for (y = 0; y < 8; y++) {
    for (x = 0; x < 8; x++) {
        d[y][x] = f[y][x] + p[y][x];
        if (d[y][x] <  0) d[y][x] = 0;
        if (d[y][x] > 255) d[y][x] = 255;
    }
}
```

7.7 Spatial scalability

This subclause specifies the additional decoding process required for the spatial scalable extensions.

Both the lower layer and the enhancement layer shall use the "restricted slice structure" (no gaps between slices).

Figure 7-13 is a diagram of the video decoding process with spatial scalability. The diagram is simplified for clarity.

7.7.1 Higher syntactic structures

In general, the base layer of a spatial scalable hierarchy can conform to any coding standard including Recommendation ITU-T H.261, ISO/IEC 11172-2 and this Specification. Note however, that within this Specification the decodability of a spatial scalable hierarchy is only considered in the case that the base layer conforms to this Specification or ISO/IEC 11172-2.

Due to the "loose coupling" of layers only one syntactic restriction is needed in the enhancement layer if both lower and enhancement layer are interlaced. In that case picture_structure has to take the same value as in the reference frame used for prediction from the lower layer. See 7.7.3.1 for how to identify this reference frame.

7.7.2 Prediction in the enhancement layer

A motion compensated temporal prediction is made from reference frames in the enhancement layer as described in 7.6. In addition, a spatial prediction is formed from the lower layer decoded frame ($d_{lower}[y][x]$), as described in 7.7.3. These predictions are selected individually or combined to form the actual prediction.

In general, up to four separate predictions are formed for each macroblock which are combined together to form the final prediction macroblock p[y][x].

In the case that a macroblock is not coded, either because the entire macroblock is skipped or the specific macroblock is not coded, there is no coefficient data. In this case f[y][x] is zero and the decoded samples are simply the prediction, p[y][x].

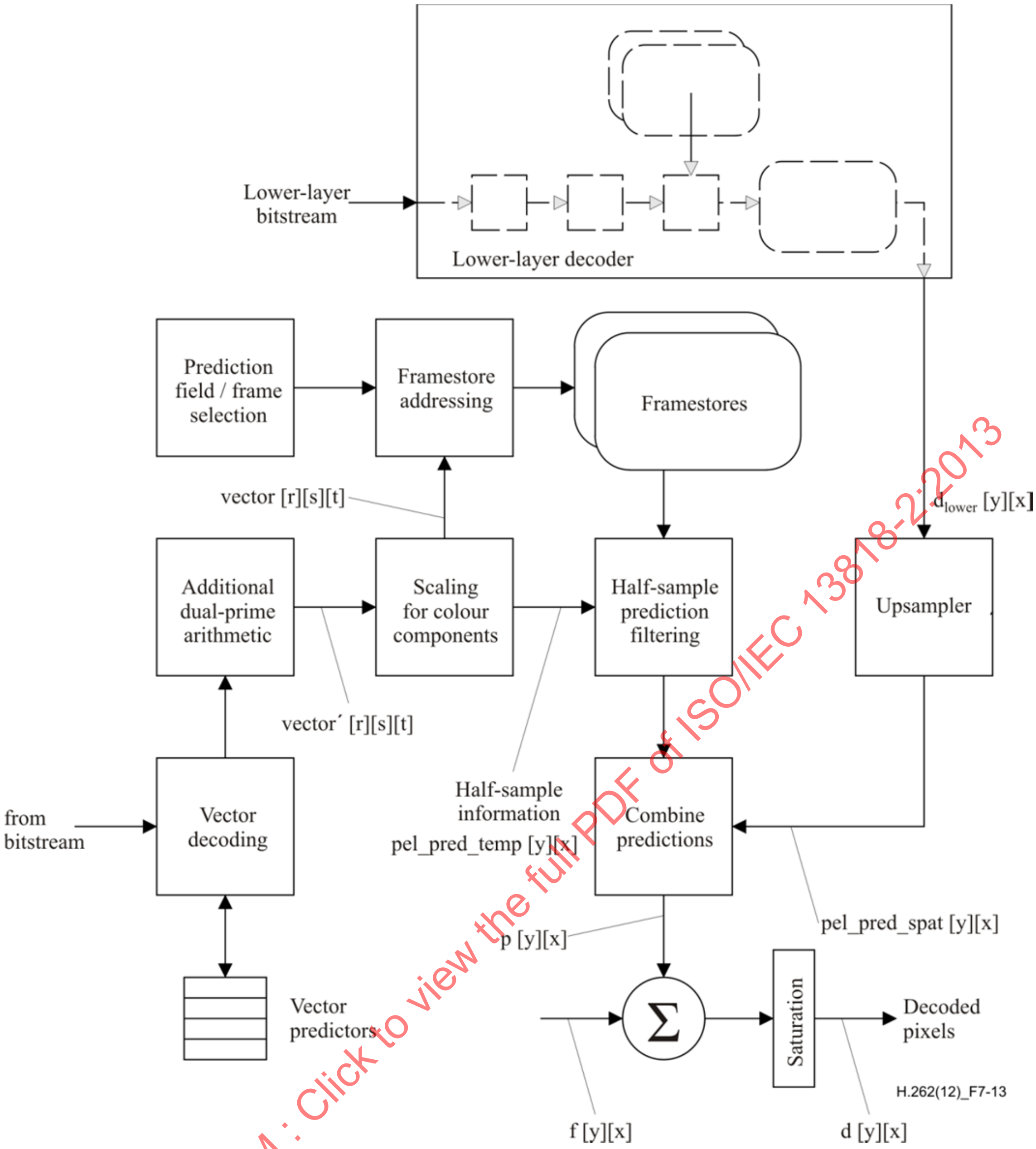


Figure 7-13 – Simplified motion compensation process for spatial scalability

7.7.3 Formation of spatial prediction

Forming the spatial prediction requires identification of the correct reference frame and definition of the spatial resampling process, which is done in the following subclauses.

The resampling process is defined for a whole frame, however, for decoding of a macroblock, only the 16 × 16 region in the upsampled frame, which corresponds to the position of this macroblock, is needed.

7.7.3.1 Selection of reference frame

The spatial prediction is made from the reconstructed frame of the lower layer referenced by the lower_layer_temporal_reference. However, if lower and enhancement layer bitstreams are embedded in Rec. ITU-T H.220.0 | ISO/IEC 13818-1 (Systems) multiplex, this information is overridden by the timing information given by the decoding time stamps (DTS) in the PES headers.

NOTE – If group_of_pictures_header() occurs often in the lower layer bitstream, then the temporal reference in the lower layer may be ambiguous (because temporal_reference is reset after a group_of_pictures_header()).

The reconstructed picture from which the spatial prediction is made shall be one of the following:

- The coincident or most recently decoded lower layer picture.
- The coincident or most recently decoded lower layer I-picture or P-picture.

- The second most recently decoded lower layer I-picture or P-picture provided that the lower layer does not have low_delay set to '1'. Note furthermore that spatial scalability will only work efficiently when predictions are formed from frames in the lower layer which are also coincident (or very close) in display time with the predicted frame in the enhancement layer.

7.7.3.2 Resampling process

The spatial prediction is made by resampling the lower layer reconstructed frame to the same sample grid as the enhancement layer. This grid is defined in terms of frame coordinates, even if a lower-layer interlaced frame was actually coded with a pair of field pictures.

This resampling process is illustrated in Figure 7-14.

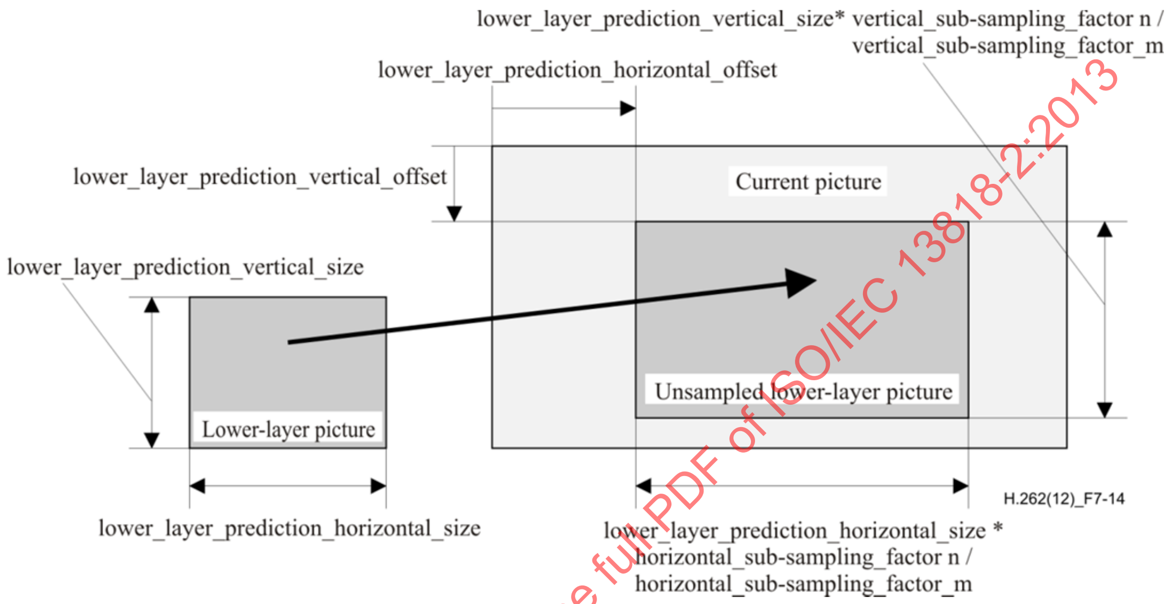


Figure 7-14 – Formation of the "spatial" prediction by interpolation of the lower-layer picture

Spatial predictions shall only be made for macroblocks in the enhancement layer that lie wholly within the upsampled lower layer reconstructed frame.

The upsampling process depends on whether the lower layer reconstructed frame is interlaced or progressive, as indicated by lower_layer_progressive_frame and whether the enhancement layer frame is interlaced or progressive, as indicated by progressive_frame.

When lower_layer_progressive_frame is '1', the lower layer reconstructed frame (renamed to prog_pic) is resampled vertically as described in 7.7.3.4. The resulting frame is considered to be progressive if progressive_frame is '1' and interlaced if progressive_frame is '0'. The resulting frame is resampled horizontally as described in 7.7.3.6. lower_layer_deinterlaced_field_select shall have the value '1'.

When lower_layer_progressive_frame is '0' and progressive_frame is '0', each lower layer reconstructed field is deinterlaced as described in 7.7.3.4, to produce a progressive field (prog_pic). This field is resampled vertically as described in 7.7.3.5. The resulting field is resampled horizontally as described in 7.7.3.6. Finally the resulting field is subsampled to produce an interlaced field. lower_layer_deinterlaced_field_select shall have the value '1'.

When lower_layer_progressive_frame is '0' and progressive_frame is '1', each lower layer reconstructed field is deinterlaced as described in 7.7.3.4, to produce a progressive field (prog_pic). Only one of these fields is required. When lower_layer_deinterlaced_field_select is '0' the top field is used, otherwise the bottom field is used. The one that is used is resampled vertically as described in 7.7.3.5. The resulting frame is resampled horizontally as described in 7.7.3.6.

For interlaced frames, if the current (and implicitly the lower-layer) frames are encoded as field pictures, the deinterlacing process described in 7.7.3.5 is done within the field.

lower_layer_vertical_offset and lower_layer_horizontal_offset, defining the position of the lower layer frame within the current frame, shall be taken into account in the resampling definitions in 7.7.3.5 and 7.7.3.6 respectively. The lower layer offsets are limited to even values when the chrominance in the enhancement layer is subsampled in that dimension in order to align the chrominance samples between the two layers.

The upsampling process is summarised Table 7-15.

Table 7-15 – Upsampling process

lower_layer_deinterlaced_field_select	lower_layer_progressive_frame	progressive_frame	Apply deinterlace process	Entity used for prediction
0	0	1	Yes	Top field
1	0	1	Yes	Bottom field
1	1	1	No	Frame
1	1	0	No	Frame
1	0	0	Yes	Both fields

7.7.3.3 Colour component processing

Due to the different sampling grids of luminance and chrominance components, some variables used in 7.7.3.4 to 7.7.3.6 take different values for luminance and chrominance resampling. Furthermore it is permissible for the chrominance formats in the lower layer and the enhancement layer to be different from one another.

Table 7-16 defines the values for the variables used in 7.7.3.4 to 7.7.3.6

Table 7-16 – Local variables used in 7.7.3.3 to 7.7.3.6

Variable	Value for luminance processing	Value for chrominance processing
ll_h_size	lower_layer_prediction_horizontal_size	lower_layer_prediction_horizontal_size / chroma_ratio_horizontal[lower]
ll_v_size	lower_layer_prediction_vertical_size	lower_layer_prediction_vertical_size / chroma_ratio_vertical[lower]
ll_h_offset	lower_layer_horizontal_offset	lower_layer_horizontal_offset / chroma_ratio_horizontal[enhance]
ll_v_offset	lower_layer_vertical_offset	lower_layer_vertical_offset / chroma_ratio_vertical[enhance]
h_subs_m	horizontal_subsampling_factor_m	horizontal_subsampling_factor_m
h_subs_n	horizontal_subsampling_factor_n	horizontal_subsampling_factor_n * format_ratio_horizontal
v_subs_m	vertical_subsampling_factor_m	vertical_subsampling_factor_m
v_subs_n	vertical_subsampling_factor_n	vertical_subsampling_factor_n * format_ratio_vertical

Tables 7-17 and 7-18 give additional definitions.

Table 7-17 – chrominance subsampling ratios for layer = {lower, enhance}

Chrominance format lower layer	chroma_ratio_horizontal[layer]	chroma_ratio_vertical[layer]
4:2:0	2	2
4:2:2	2	1
4:4:4	1	1

Table 7-18 – Chrominance format ratios

Chrominance format lower layer	Chrominance format enhancement layer	format_ratio_ horizontal	format_ratio_ vertical
4:2:0	4:2:0	1	1
4:2:0	4:2:2	1	2
4:2:0	4:4:4	2	2
4:2:2	4:2:2	1	1
4:2:2	4:4:4	2	1
4:4:4	4:4:4	1	1

7.7.3.4 Deinterlacing

If deinterlacing needs not to be done (according to Table 7-16), the lower layer reconstructed frame (d_{lower}[y][x]) is renamed to input_pic.

First, each lower layer field is padded with zeros to form a progressive grid at a frame rate equal to the field rate of the lower layer, and with the same number of lines and samples per line as the lower layer frame. Table 7-19 specifies the filters to be applied next. The luminance component is filtered using the relevant two field aperture filter if picture_structure == "Frame-picture" or else using the one field aperture filter. The chrominance component is filtered using the one field aperture filter.

Table 7-19 – Deinterlacing Filter

Temporal	Vertical	Two field aperture		One field aperture
		Filter for first field	Filter for second field	Filter (both fields)
–1	–2	0	–1	0
–1	0	0	2	0
–1	2	0	–1	0
0	–1	8	8	8
0	0	16	16	16
0	1	8	8	8
1	–2	–1	0	0
1	0	2	0	0
1	+2	–1	0	0

The temporal and vertical columns of Table 7-19 indicate the relative spatial and temporal coordinates of the samples to which the filter taps defined in the other two columns apply. An intermediate sum is formed by adding the multiplied coefficients together.

The output of the filter (sum) is then scaled according to the following formula:

$$prog\_pic[y][x] = sum // 16$$

and saturated to lie in the range [0:255].

The filter aperture can extend outside the coded picture size. In this case the samples of the lines outside the active picture shall take the value of the closest neighbouring existing sample (below or above) of the same field as defined below.

For all samples [y][x]:

```
if (y < 0 && (y&1 == 1))
    y = 1
if (y < 0 && (y&1 == 0))
    y = 0
if (y >= ll_v_size &&
            ( (y-ll_v_size)&1 == 1))
    y = ll_v_size – 1
if (y >= ll_v_size &&
            ((y-ll_v_size)&1 == 0))
    y = ll_v_size – 2
```

7.7.3.5 Vertical resampling

The frame subject to vertical resampling, prog_pic, is resampled to the enhancement layer vertical sampling grid using linear interpolation between the sample sites according to the following formula, where vert_pic is the resulting field:

$$\text{vert\_pic}[y_h + \text{ll\_v\_offset}][x] = (16 - \text{phase}) * \text{prog\_pic}[y1][x] + \text{phase} * \text{prog\_pic}[y2][x]$$

where

y_h + ll_v_offset	=	output sample co-ordinate in vert_pic
y1	=	(y_h ∗ v_subs_m) / v_subs_n
y2	=	y1 + 1 if y1 < ll_v_size – 1
		y1 otherwise

phase = (16 * ((y_h * v_subs_m) % v_subs_n)) // v_subs_n

Samples which lie outside the lower layer reconstructed frame which are required for upsampling are obtained by border extension of the lower layer reconstructed frame.

NOTE – The calculation of phase assumes that the sample position in the enhancement layer at $y_h = 0$ is spatially coincident with the first sample position of the lower layer. It is recognised that this is an approximation for the chrominance component if the chroma_format == 4:2:0.

7.7.3.6 Horizontal resampling

The frame subject to horizontal resampling, vert_pic, is resampled to the enhancement layer horizontal sampling grid using linear interpolation between the sample sites according to the following formula, where hor_pic is the resulting field:

$$\text{hor\_pic}[y][x_h + \text{ll\_h\_offset}] = ((16 - \text{phase}) * \text{vert\_pic}[y][x1] + \text{phase} * \text{vert\_pic}[y][x2]) \,//\, 256$$

where

x_h+ ll_h_offset	=	output sample coordinate in hor_pic
x1	=	(x_h * h_subs_m) / h_subs_n
x2	=	x1 + 1 if x1 < ll_h_size - 1
		x1 otherwise

phase = (16 * ((x_h * h_subs_m) % h_subs_n)) // h_subs_n

Samples which lie outside the lower layer reconstructed frame which are required for upsampling are obtained by border extension of the lower layer reconstructed frame.

7.7.3.7 Reinterlacing

If reinterlacing needs not to be done, the result of the resampling process, hor_pic, is renamed to spat_pred_pic.

If hor_pic was derived from the top field of a lower layer interlaced frame, the even lines of hor_pic are copied to the even lines of spat_pred_pic.

If hor_pic was derived from the bottom field of a lower layer interlaced frame the odd lines of hor_pic are copied to the odd lines of spat_pred_pic.

If hor_pic was derived from a lower layer progressive frame, hor_pic is copied to spat_pred_pic.

7.7.4 Selection and combination of spatial and temporal predictions

The spatial and temporal predictions can be selected or combined to form the actual prediction. The macroblock_type (see Tables B.5, B.6 and B.7) and the additional spatial_temporal_weight_code (see Table 7-21) indicate, by use of the spatial_temporal_weight_class, whether the prediction is temporal-only, spatial-only or a weighted combination of temporal and spatial predictions. Classes are defined in the following way:

- Class 0 indicates temporal-only prediction;
- Class 1 indicates that neither field has spatial-only prediction;
- Class 2 indicates that the top field is spatial-only prediction;
- Class 3 indicates that the bottom field is spatial-only prediction;
- Class 4 indicates spatial-only prediction.

In intra pictures, if spatial_temporal_weight_class is 0, normal intra coding is performed; otherwise, the prediction is spatial-only. In predicted and interpolated pictures, if the spatial_temporal_weight_class is 0, prediction is temporal-only, if the spatial_temporal_weight_class is 4, prediction is spatial-only; otherwise, one or a pair of prediction weights is used to combine the spatial and temporal predictions.

The possible spatial_temporal_weights are given in a weight table which is selected in the picture spatial scalable extension. Up to four different weight tables are available for use depending on whether the current and lower layers are interlaced or progressive, as indicated in Table 7-20 (allowed, yet not recommended, values given in brackets).

Table 7-20 – Intended (allowed) spatial_temporal_weight_code_table_index values

Lower layer format	Enhancement layer format	**spatial_temporal_weight_code_table_index**
Progressive or interlaced	Progressive	00
Progressive coincident with enhancement layer top fields	Interlaced	10 (00; 01; 11)
Progressive coincident with enhancement layer from bottom fields	Interlaced	01 (00; 10; 11)
Interlaced (picture_structure == Frame-picture)	Interlaced	00 or 11 (01; 10)
Interlaced (picture_structure != Frame-picture)	Interlaced	00

In macroblock_modes(), a two bit code, spatial_temporal_weight_code, is used to describe the prediction for each field (or frame), as shown in Table 7-21. In this table spatial_temporal_integer_weight identifies those spatial_temporal_weight_codes that can also be used with dual prime prediction (see Tables 7-22, 7-23).

Table 7-21 – spatial_temporal_weights and spatial_temporal_weight_classes for the spatial_temporal_weight_code_table_index and spatial_temporal_weight_codes

spatial_temporal_weight_code_table_index	spatial_temporal_weight_code	spatial_temporal_weight (s)	spatial_temporal_weight class	spatial_temporal_integer_weight
00[a)]	–	(0,5)	1	0
01	00	(0; 1)	3	1
	01	(0; 0,5)	1	0
	10	(0,5; 1)	3	0
	11	(0,5; 0,5)	1	0
10	00	(1; 0)	2	1
	01	(0,5; 0)	1	0
	10	(1; 0,5)	2	0
	11	(0,5; 0,5)	1	0
11	00	(1; 0)	2	1
	01	(1; 0,5)	2	0
	10	(0,5; 1)	3	0
	11	(0,5; 0,5)	1	0

a) For spatial_temporal_weight_code_table_index == 00 no spatial_temporal_weight_code is transmitted.

NOTE – Spatial-only prediction (weight_class == 4) is signalled by different values of macroblock_type (see Tables B.5 to B.7).

When the spatial_temporal_weight combination is given in the form (a; b), "a" gives the proportion of the prediction for the top field which is derived from the spatial prediction and "b" gives the proportion of the prediction for the bottom field which is derived from the spatial prediction for that field.

When the spatial_temporal_weight is given in the form (a), "a" gives the proportion of the prediction for the picture which is derived from the spatial prediction for that picture.

The precise method for predictor calculation is as follows:

pel_pred_temp[y][x] is used to denote the temporal prediction (formed within the enhancement layer) as defined for pel_pred[y][x] in 7.6. pel_pred_spat[y][x] is used to denote the prediction formed from the lower layer by extracting the appropriate samples, co-located with the current macroblock position, from spat_pred_pic.

If the spatial_temporal_weight is zero, then no prediction is made from the lower layer. Therefore:

$$\text{pel\_pred}[y][x] = \text{pel\_pred\_temp}[y][x];$$

If the spatial_temporal_weight is one, then no prediction is made from the enhancement layer. Therefore:

$$\text{pel\_pred}[y][x] = \text{pel\_pred\_spat}[y][x];$$

If the weight is one half then the prediction is the average of the temporal and spatial predictions. Therefore:

$$\text{pel\_pred}[y][x] = (\text{pel\_pred\_temp}[y][x] + \text{pel\_pred\_spat}[y][x])//2;$$

When progressive_frame == 0 chrominance is treated as interlaced, that is, the first weight is used for the top field chrominance lines and the second weight is used for the bottom field chrominance lines.

Addition of prediction and coefficient data is then done as in 7.6.8.

7.7.5 Updating motion vector predictors and motion vector selection

In frame pictures where field prediction is used the possibility exists that one of the fields is predicted using spatial-only prediction. In this case no motion vector is present in the bitstream for the field which has spatial-only prediction. For the case where both fields of a frame have spatial-only prediction, the macroblock_type is such that no motion vectors are present in the bitstream for that macroblock.

The spatial_temporal_weight_class also indicates the number of motion vectors which are present in the coded bitstream and how the motion vector predictors are updated as defined in Table 7-22 and Table 7-23.

Table 7-22 – Updating of motion vector predictors in field pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Predictors to update
Field-based[a]	–	–	1	0	PMV[1][0][1:0] = PMV[0][0][1:0][b]
Field-based	1	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0] PMV[1][1][1:0] = PMV[0][1][1:0]
Field-based	1	0	0	0,1	PMV[1][0][1:0] = PMV[0][0][1:0]
Field-based	0	1	0	0,1	PMV[1][1][1:0] = PMV[0][1][1:0]
Field-based[a]	0	0	0	0,1,4	PMV[r][s][t] = 0[c]
16 × 8 MC	1	1	0	0	(None)
16 × 8 MC	1	0	0	0,1	(None)
16 × 8 MC	0	1	0	0,1	(None)
Dual prime	1	0	0	0	PMV[1][0][1:0] = PMV[0][0][1:0]

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) If **concealment_motion_vectors** is zero then PMV[r][s][t] is set to zero (for all r, s and t).

c) PMV[r][s][t] is set to zero (for all r, s and t). See 7.6.3.4.

NOTE – PMV[r][s][1:0] = PMV[u][v][1:0] means that:

PMV[r][s][1] = PMV[u][v][1] and PMV[r][s][0] = PMV[u][v][0]

7.7.5.1 Resetting motion vector predictors

In addition to the cases identified in 7.6.3.4, the motion vector predictors shall be reset in the following cases:

- In a P-picture when a macroblock is purely spatially predicted (spatial_temporal_weight_class == 4)
- In a B-picture when a macroblock is purely spatially predicted (spatial_temporal_weight_class == 4)

NOTE – In case of spatial_temporal_weight_class == 2 in a frame picture when field-based prediction is used, the transmitted vector is applied for the bottom field (see Table 7-25). However this vector[0][s][1:0] is predicted from PMV[0][s][1:0]. PMV[1][s][1:0] is then updated as shown in Table 7-23.

7.7.6 Skipped macroblocks

In all cases, a skipped macroblock is the result of a prediction only, and all the DCT coefficients are considered to be zero.

If sequence_scalable_extension is present and scalable_mode = "spatial scalability", the following rules apply in addition to those given in 7.6.6.

Table 7-23 – Updating of motion vector predictors in frame pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Predictors to update
Frame-based[a]	–	–	1	0	PMV[1][0][1:0] = PMV[0][0][1:0][c]
Frame-based	1	1	0	0	PMV[1][0][1:0] = PMV[0][0][1:0] PMV[1][1][1:0] = PMV[0][1][1:0]
Frame-based	1	0	0	0,1,2,3	PMV[1][0][1:0] = PMV[0][0][1:0]
Frame-based	0	1	0	0,1,2,3	PMV[1][1][1:0] = PMV[0][1][1:0]
Frame-based[a]	0	0	0	0,1,2,3,4	PMV[r][s][t] = 0[d]
Field-based	1	1	0	0	(None)
Field-based	1	0	0	0,1	(None)
Field-based	1	0	0	2	PMV[1][0][1:0] = PMV[0][0][1:0]
Field-based	1	0	0	3	PMV[1][0][1:0] = PMV[0][0][1:0]
Field-based	0	1	0	0,1	(None)
Field-based	0	1	0	2	PMV[1][1][1:0] = PMV[0][1][1:0]
Field-based	0	1	0	3	PMV[1][1][1:0] = PMV[0][1][1:0]
Dual prime[b]	1	0	0	0,2,3	PMV[1][0][1:0] = PMV[0][0][1:0]

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) Dual prime can not be used when spatial_temporal_integer_weight = '0'.

c) If **concealment_motion_vectors** is zero then PMV[r][s][t] is set to zero (for all r, s and t).

d) PMV[r][s][t] is set to zero (for all r, s and t). See 7.6.3.4.

NOTE –PMV[r][s][1:0] = PMV[u][v][1:0] means that:

PMV[r][s][1] = PMV[u][v][1] and PMV[r][s][0] = PMV[u][v][0]

In I-pictures, skipped macroblocks are allowed. These are defined as spatial-only predicted.

In P-pictures and B-pictures, the skipped macroblock is temporal-only predicted.

In B-pictures a skipped macroblock shall not follow a spatial-only predicted macroblock.

7.7.7 VBV buffer underflow in the lower layer

In the case of spatial scalability, VBV buffer underflow in the lower layer may cause problems. This is because of possible uncertainty in precisely which frames will be repeated by a particular decoder.

7.8 SNR scalability

See Figure 7-15.

This clause describes the additional decoding process required for the SNR scalable extensions.

SNR scalability defines a mechanism to refine the DCT coefficients encoded in another (lower) layer of a scalable hierarchy. As illustrated in Figure 7-15, data from two bitstreams is combined after the inverse quantization processes by adding the DCT coefficients. Until the data is combined, the decoding processes of the two layers are independent of one another.

Table 7-24 – Predictions and motion vectors in field pictures

field_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Motion vector	Prediction formed for
Field-based [a)]	–	–	1	0	vector'[0][0][1:0] [b)]	None (motion vector is for concealment)
Field-based	1	1	0	0	vector'[0][0][1:0]	Whole field, forward
					vector'[0][1][1:0]	Whole field, backward
Field-based	1	0	0	0,1	vector'[0][0][1:0]	Whole field, forward
Field-based	0	1	0	0,1	vector'[0][1][1:0]	Whole field, backward
Field-based [a)]	0	0	0	0,1,4	vector'[0][0][1:0] [c) d)]	Whole field, forward
16 × 8 MC	1	1	0	0	vector'[0][0][1:0]	Upper 16 × 8 field, forward
					vector'[1][0][1:0]	Lower 16 × 8 field, forward
					vector'[0][1][1:0]	Upper 16 × 8 field, backward
					vector'[1][1][1:0]	Lower 16 × 8 field, backward
16 × 8 MC	1	0	0	0,1	vector'[0][0][1:0]	Upper 16 × 8 field, forward
					vector'[1][0][1:0]	Lower 16 × 8 field, forward
16 × 8 MC	0	1	0	0,1	vector'[0][1][1:0]	Upper 16 × 8 field, backward
					vector'[1][1][1:0]	Lower 16 × 8 field, backward
Dual prime	1	0	0	0	vector'[0][0][1:0]	Whole field, same parity, forward
					vector'[2][0][1:0] [c) e)]	Whole field, opposite parity, forward

a) **field_motion_type** is not present in the bitstream but is assumed to be Field-based.

b) The motion vector is only present if **concealment_motion_vectors** is one.

c) These motion vectors are not present in the bitstream.

d) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

e) These motion vectors are derived from vector'[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

Subclause 7.8.1 defines how to identify these bitstreams in a scalable hierarchy; however, they can be classified as follows.

The lower layer, derived from the first bitstream, can itself be either non-scalable, or require the spatial or temporal scalability decoding process (and hence the decoding of additional bitstreams) to be applied.

The enhancement layer, derived from the second bitstream, contains mainly coded DCT coefficients and a small overhead. The decoding process for this layer and the combination of the two layers are described in this subclause.

NOTE – All information regarding prediction is contained in the lower layer bitstream only. Therefore it is not possible to reconstruct an enhancement layer without decoding the lower layer bitstream data in parallel.

Furthermore prediction and reconstruction of the pictures as described in 7.6, 7.7 and 7.9 for the combined lower and enhancement layer is identical to the respective steps for decoding of the lower layer bitstream only.

Semantics and decoding process described in this subclause include a mechanism for "chroma simulcast". This may be used (for instance) to enhance 4:2:0 in the lower layer to 4:2:2 after processing the enhancement layer data. While the luminance data is processed as described before, in this case the chrominance information retrieved from the lower layer bitstream (with exception of intra-DC values, see 7.8.3.4) shall be discarded and replaced by the new information with higher chrominance resolution decoded from the enhancement layer.

Table 7-25 – Predictions and motion vectors in frame pictures

frame_motion_type	**macroblock_motion_forward**	**macroblock_motion_backward**	**macroblock_intra**	**spatial_temporal_weight_class**	Motion vector	Prediction formed for
Frame-based[a)]	–	–	1	0	vector'[0][0][1:0][c)]	None (motion vector is for concealment)
Frame-based	1	1	0	0	vector'[0][0][1:0]	Frame, forward
					vector'[0][1][1:0]	Frame, backward
Frame-based	1	0	0	0,1,2,3	vector'[0][0][1:0]	Frame, forward
Frame-based	0	1	0	0,1,2,3	vector'[0][1][1:0]	Frame, backward
Frame-based[a)]	0	0	0	0,1,2,3,4	vector'[0][0][1:0][d) e)]	Frame, forward
Field-based	1	1	0	0	vector'[0][0][1:0]	Top field, forward
					vector'[1][0][1:0]	Bottom field, forward
					vector'[0][1][1:0]	Top field, backward
					vector'[1][1][1:0]	Bottom field, backward
Field-based	1	0	0	0,1	vector'[0][0][1:0]	Top field, forward
					vector'[1][0][1:0]	Bottom field, forward
Field-based	1	0	0	2		Top field, spatial
					vector'[0][0][1:0]	Bottom field, forward
Field-based	1	0	0	3	vector'[0][0][1:0]	Top field, forward
						Bottom field, spatial
Field-based	0	1	0	0,1	vector'[0][1][1:0]	Top field, backward
					vector'[1][1][1:0]	Bottom field, backward
Field-based	0	1	0	2		Top field, spatial
					vector'[0][1][1:0]	Bottom field, backward
Field-based	0	1	0	3	vector'[0][1][1:0]	Top field, backward
						Bottom field, spatial
Dual prime[b)]	1	0	0	0,2,3	vector'[0][0][1:0]	Top field, same parity, forward
					vector'[0][0][1:0][d)]	Bottom field, same parity, forward
					vector'[2][0][1:0][d) f)]	Top field, opposite parity, forward
					vector'[3][0][1:0][d) f)]	Bottom field, opposite parity, forward

a) **frame_motion_type** is not present in the bitstream but is assumed to be Frame-based.

b) Dual prime cannot be used when spatial_temporal_integer_weight = '0'.

c) The motion vector is only present if **concealment_motion_vectors** is one.

d) These motion vectors are not present in the bitstream.

e) The motion vector is taken to be (0; 0) as explained in 7.6.3.5.

f) These motion vectors are derived from vector'[0][0][1:0] as described in 7.6.3.6.

NOTE – Motion vectors are listed in the order they appear in the bitstream.

It is inherent in SNR scalability that the two layers are very tightly coupled to one another. It is a requirement that corresponding pictures in each layer shall be decoded at the same time as one another.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then two different IDCT mismatch control schemes are being used in decoding. Care must be taken in the encoder to take account of this.

7.8.1 Higher syntactic structures

The two bitstream layers in this subclause are identified by their layer_id, decoded from the sequence_scalable_extension.

The two bitstreams shall have consecutive layer ids, with enhancement layer bitstream having layer_id = $id_{enhance}$ and the lower layer bitstream having layer_id = $id_{enhance}-1$.

The syntax and semantics of the enhancement layer are as defined in 6.2 and 6.3, respectively.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then both this lower and the enhancement layer shall use the "restricted slice structure" defined in this Specification.

Semantic restrictions apply to several values in the headers and extensions of the enhancement layer as follows.

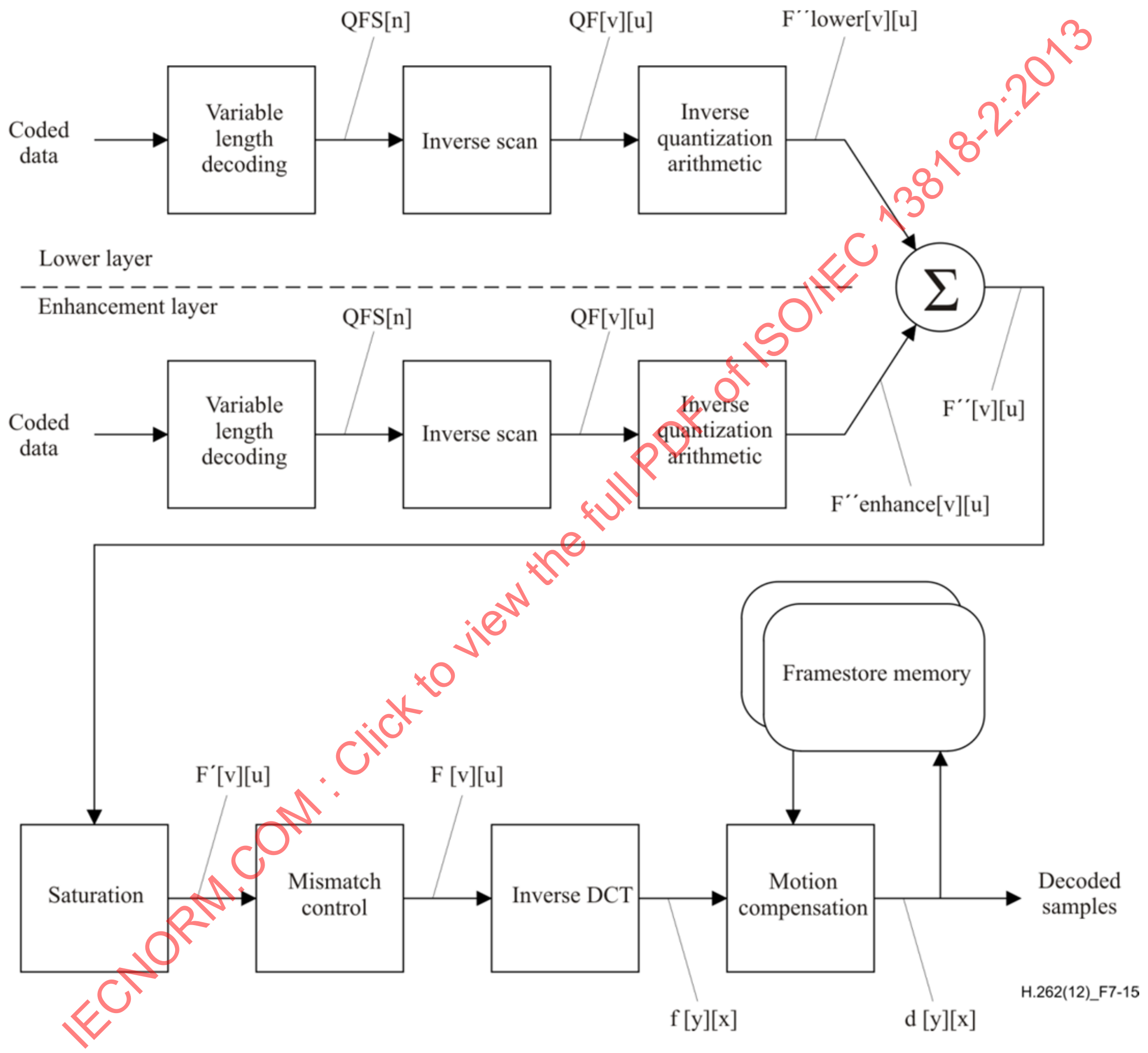


Figure 7-15 – Illustration of decoding process for SNR scalability

Sequence header

This header shall be identical to the one in the lower layer bitstream except for the values of bit_rate, vbv_buffer_size, load_intra_quantiser_matrix, intra_quantiser_matrix, load_non_intra_quantiser_matrix and non_intra_quantiser_matrix. These can be selected independently except for load_intra_quantiser_matrix which shall be zero.

Sequence extension

This extension shall be identical to the one in the lower layer bitstream except for the values of profile_and_level_indication, chroma_format, bit_rate_extension and vbv_buffer_size_extension. Those can be selected independently.

A different value of chroma_format in each layer will cause the chroma_simulcast flag to be set as specified by Table 7-26.

Table 7-26 – chroma_simulcast flag

chroma_format (lower layer)	chroma_format (enhancement layer)	chroma_simulcast
4:2:0	4:2:0	0
4:2:0	4:2:2	1
4:2:0	4:4:4	1
4:2:2	4:2:2	0
4:2:2	4:4:4	1
4:4:4	4:4:4	0

The chroma_format of the enhancement layer shall be higher or equal to the chroma_format of the lower layer bitstream.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not This Specification), sequence_extension() is not present in the lower layer bitstream, and the following values shall be assumed for the decoding process.

progressive_sequence	=	1
chroma_format	=	"4:2:0"
horizontal_size_extension	=	0
vertical_size_extension	=	0
bit_rate_extension	=	0
vbv_buffer_size_extension	=	0
low_delay	=	0
frame_rate_extension_n	=	0
frame_rate_extension_d	=	0

The sequence_extension() in the enhancement layer shall have the values shown above.

Sequence display extension

This extension shall not be present as there is no separate display process for the enhancement layer.

Sequence scalable extension

This extension shall be present with scalable_mode = "SNR scalability".

GOP header

This header shall be identical to the one in the lower layer bitstream.

NOTE 1 – The GOP header must be present in each layer in order that the temporal_reference in each layer are reset on the same frame.

Picture header

This header shall be identical to the one in the lower layer bitstream except for the value of vbv_delay. This can be selected independently.

Picture coding extension

This extension shall be identical to the one in the lower layer bitstream except for the value of q_scale_type and alternate_scan. These can be selected independently.

chroma_420_type shall be set to '0' if chroma_simulcast is set. Else, it shall have the same value as in the lower layer bitstream.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then picture_coding_extension() is not present in the lower layer bitstream and the following values shall be assumed for the decoding process:

f_code[0][0]	=	forward_f_code in the lower layer bitstream or 15
f_code[0][1]	=	forward_f_code in the lower layer bitstream or 15

f_code[1][0]	=	backward_f_code in the lower layer bitstream or 15
f_code[1][1]	=	backward_f_code in the lower layer bitstream or 15
intra_dc_precision	=	0
picture_structure	=	"Frame-picture"
top_field_first	=	0
frame_pred_frame_dct	=	1
concealment_motion_vectors	=	0
intra_vlc_format	=	0
repeat_first_field	=	0
chroma_420_type	=	1
progressive_frame	=	1
composite_display_flag	=	0

The picture_coding_extension() in the enhancement layer shall have the values shown above.

For the lower layer q_scale_type and alternate_scan shall be assumed to have the value zero.

NOTE 2 – q_scale_type and alternate_scan can be set independently in the enhancement layer.

Quant matrix extension

This extension is optional. Semantics are described in 6.3.11.

load_intra_quantiser_matrix and load_chroma_intra_quantiser_matrix shall both be zero.

NOTE 3 – Only the non-intra matrices will be used in the subsequent decoding process.

Picture display extension

This extension shall not be present.

NOTE 4 – There is no separate display process for the enhancement layer. If pan-scan functionality is desired, it can be accomplished already by using the information conveyed by the pan-scan extension of the lower layer bitstream.

Slice header

Slices shall be coincident with those in the lower layer. The value of quantiser_scale_code can be set independently from the lower layer bitstream.

7.8.2 Macroblock

Subsequently the "current macroblock" denotes the currently processed macroblock. The current macroblock of the lower layer denotes the macroblock identified by having the same macroblock_address as the current macroblock.

The decoding of the macroblock header information is done according to semantics in 6.3.17.

NOTE – Table B.8 which is used if scalable_mode = = "SNR scalability" will never set the macroblock_intra, macroblock_motion_forward or macroblock_motion_backward flags, since a macroblock in the enhancement layer contains only refinement data for the current macroblock of the lower layer.

However the corresponding syntax elements and flags of the current macroblock in the lower layer bitstream are relevant for the combined decoding process of lower and enhancement layer following the inverse DCT as described in 7.8.3.5.

7.8.2.1 dct_type

The syntax element dct_type may be present in none, one or both of the lower and enhancement layer macroblock_modes(), as indicated by the semantics in 6.3.17.

If dct_type is present in the macroblock_modes() in both layers it shall have identical values.

7.8.2.2 Skipped Macroblocks

Macroblocks can be skipped in the enhancement layer bitstream, meaning that no coefficient enhancement is done ($F''_{enhance}[v][u] = 0$, for all v, u). Regarding this, the decoding process detailed in 7.8.3 shall be applied.

When macroblocks are skipped in both, the lower and the enhancement layer bitstreams, the decoding process is exactly as specified in 7.6.6.

Macroblocks can also be skipped in the lower layer bitstream, while still being coded in the enhancement layer bitstream. In that case the decoding process detailed in the following has to be applied, but $F''_{lower}[v][u] = 0$, for all v, u.

7.8.3 Block

The first part of the decoding process of the enhancement layer block is independent from the lower layer.

The second part of the decoding process of the enhancement layer block has to be done jointly with the decoding process of the coincident lower layer block.

Two sets of inverse quantized coefficients F''_{lower} and $F''_{enhance}$ are added to form F" (see Figure 7-15).

F''_{lower} is derived from the lower layer bitstream exactly as defined in 7.1 to 7.4.2.3.

$F''_{enhance}$ is derived as is defined in the clauses below.

The resulting F" is further processed, starting with saturation, as defined in 7.4.3 to 7.6 (7.7, 7.9).

7.8.3.1 Variable length decoding

In an enhancement layer block the VLC decoding shall be performed according to 7.2, as for a non-intra block (as indicated by macroblock_intra = 0).

7.8.3.2 Inverse scan

Inverse scan shall be done exactly as defined in 7.3.

7.8.3.3 Inverse quantization

In an enhancement layer block the inverse quantization shall be performed according to 7.4.2 as for a non-intra block.

In the case that the lower layer bitstream conforms to ISO/IEC 11172-2 (and not this Specification), then the "inverse quantization arithmetic" used to derive $F''_{lower}[v][u]$ (see Figure 7-14) shall include the IDCT mismatch control (oddification) and saturation specified in ISO/IEC 11172-2.

7.8.3.4 Addition of coefficients from the two layers

Corresponding coefficients from the blocks of each layer shall be added together to form F" (see Figure 7-15).

$$F''[v][u] = F''_{lower}[v][u] + F''_{enhance}[v][u], \text{ for all } u, v$$

If chroma_simulcast = 1 is set only the luminance blocks are treated as described above.

For chrominance blocks the DC coefficient of the base layer is used as a prediction of the DC coefficient in the coincident block in the enhancement layer, whereas the AC coefficients of the base layer are discarded and AC coefficients of the enhancement layer form F" in Figure 7-14 according to the following formulae:

$$F''[0][0] = F''_{lower}[0][0] + F''_{enhance}[0][0]$$

$$F''[v][u] = F''_{enhance}[v][u], \text{ for all } u, v \text{ except } u = v = 0$$

NOTE – Chroma simulcast blocks are inverse quantized like non-intra blocks and use the chrominance non-intra matrix.

Table 7-27 gives the index of the chrominance block whose DC coefficient ($F''_{lower}[0][0]$) is to be used to predict the DC coefficient in the coincident chrominance block of the enhancement layer ($F''_{enhance}[0][0]$).

Table 7-27 – Block index used to predict DC coefficient

chroma_format	Block index							
	4	5	6	7	8	9	10	11
base: 4:2:0 upper: 4:2:2	4	5	4	5				
base: 4:2:0 upper: 4:4:4	4	5	4	5	4	5	4	5
base: 4:2:2 upper: 4:4:4	4	5	6	7	4	5	6	7

7.8.3.5 Remaining macroblock decoding steps

After addition of coefficients from the two layers, the remainder of the macroblock decoding steps is exactly as described in 7.4.3 to 7.6 (7.7, 7.9, if applicable), since there is now only one data stream F"[v][u] to be processed.

In this process, the spatio/temporal prediction p[y][x] is derived according to the macroblock type syntax elements and flags for the current macroblock known from the lower layer bitstream.

7.9 Temporal scalability

Temporal scalability involves two layers, a lower layer and an enhancement layer. Both the lower and the enhancement layers process the same spatial resolution. The enhancement layer enhances the temporal resolution of the lower layer and if temporally re-multiplexed with the lower layer provides full temporal rate. This is the frame rate indicated in the enhancement layer. The decoding process for enhancement layer pictures is similar to the normal decoding process described in 7.1 to 7.6. The only difference is in the "Prediction field and frame selection" described in 7.6.2.

The reference frames for prediction are selected by reference_select_code as described in Tables 7-28 and 7-29. In P-pictures, the forward reference picture can be one of the following three: most recent enhancement picture, most recent lower layer frame, or next lower layer frame in display order. Note that in the latter case, the reference frame in lower layer used for prediction is backward in time.

Table 7-28 – Prediction references selection in P-pictures

reference_select_code	Forward prediction reference
00	Most recent decoded enhancement picture(s)
01	Most recent lower layer frame in display order
10	Next lower layer frame in display order
11	Forbidden

Table 7-29 – Prediction references selection in B-pictures

reference_select_code	Forward prediction reference	Backward prediction reference
00	Forbidden	Forbidden
01	Most recent decoded enhancement picture(s)	Most recent lower layer picture in display order
10	Most recent decoded enhancement picture(s)	Next lower layer picture in display order
11	Most recent lower layer picture in display order	Next lower layer picture in display order

In B-pictures, the forward reference can be one of the following two: most recent the enhancement pictures or most recent (or temporally coincident) lower layer frame whereas the backward reference can be one of the following two: most recent lower layer picture including temporally coincident picture in display order or next lower layer frame in display order. Note that in this case, the backward reference frame in lower layer used for prediction is forward in time.

Backward prediction cannot be made from a picture in the enhancement layer. This avoids the need for frame reordering in the enhancement layer. Motion compensation process forms predictions using lower layer decoded pictures and/or previous temporal prediction from the enhancement layer.

The enhancement layer can contain I-pictures, P-pictures or B-pictures, but B-pictures in enhancement layer behave more like P-pictures in the sense that a decoded B-picture can be used to predict the following P-pictures or B-pictures in the enhancement layer.

When the most recent frame in the lower layer is used as the reference, this includes the frame that is temporally coincident with the frame or the first field (in case of field pictures) in the enhancement layer. The prediction references used for P-picture and B-pictures are shown in Table 7-28 and Table 7-29 respectively.

The lower and enhancement layers shall use the restricted slice structure.

Figure 7-16 shows a simplified diagram of the motion compensation process for the enhancement layer using temporal scalability.

I-pictures do not use prediction references; to indicate this, the reference_select_code for I-pictures shall be '11'.

Depending on picture_coding_type, when forward_temporal_reference or backward_temporal_reference do not imply references to be used for prediction, they shall take the value 0.

7.9.1 Higher syntactic structures

The two bitstream layers in this subclause are identified by their layer_id, decoded from the sequence_scalable_extension.

The two bitstreams shall have consecutive layer ids, with enhancement layer having layer_id = $id_{enhance}$ and the lower layer having layer_id = $id_{enhance}-1$.

The syntax and semantics of enhancement layers are as defined in 6.2 and 6.3 respectively.

Semantic restrictions apply to several values in the headers and extensions of the enhancement layer as follows.

The lower layer shall conform to this Specification (and not to ISO/IEC 11172-2).

Sequence header

The values in this header can be different from the lower layer except for horizontal_size_value, vertical_size_value and aspect_ratio_information.

Sequence extension

This extension shall be identical to the one in the lower layer except for values of profile_and_level_indication, bit_rate_extension, vbv_buffer_size_extension, low_delay, frame_rate_extension_n and frame_rate_extension_d. These can be selected independently. Note that progressive_sequence indicates the scanning format of the enhancement layer frames only rather than of the output frames after multiplexing. The latter is indicated by mux_to_progressive_sequence (see sequence scalable extension).

Sequence display extension

This extension shall not be present as there is no separate display process for the enhancement layer.

Sequence scalable extension

This extension shall be present with scalable_mode = "Temporal scalability".

When progressive_sequence = 0 and mux_to_progressive_sequence = 0, top_field_first and picture_mux_factor can be selected.

When progressive_sequence = 0 and mux_to_progressive_sequence = 1, top_field_first shall contain a complement of the value of top_field_first of the lower layer but picture_mux_factor shall be 1.

When progressive_sequence = 1 and mux_to_progressive_sequence = 1, top_field_first shall be zero but picture_mux_factor can be selected.

The combination of progressive_sequence = 1 and mux_to_progressive_sequence = 0 shall not occur.

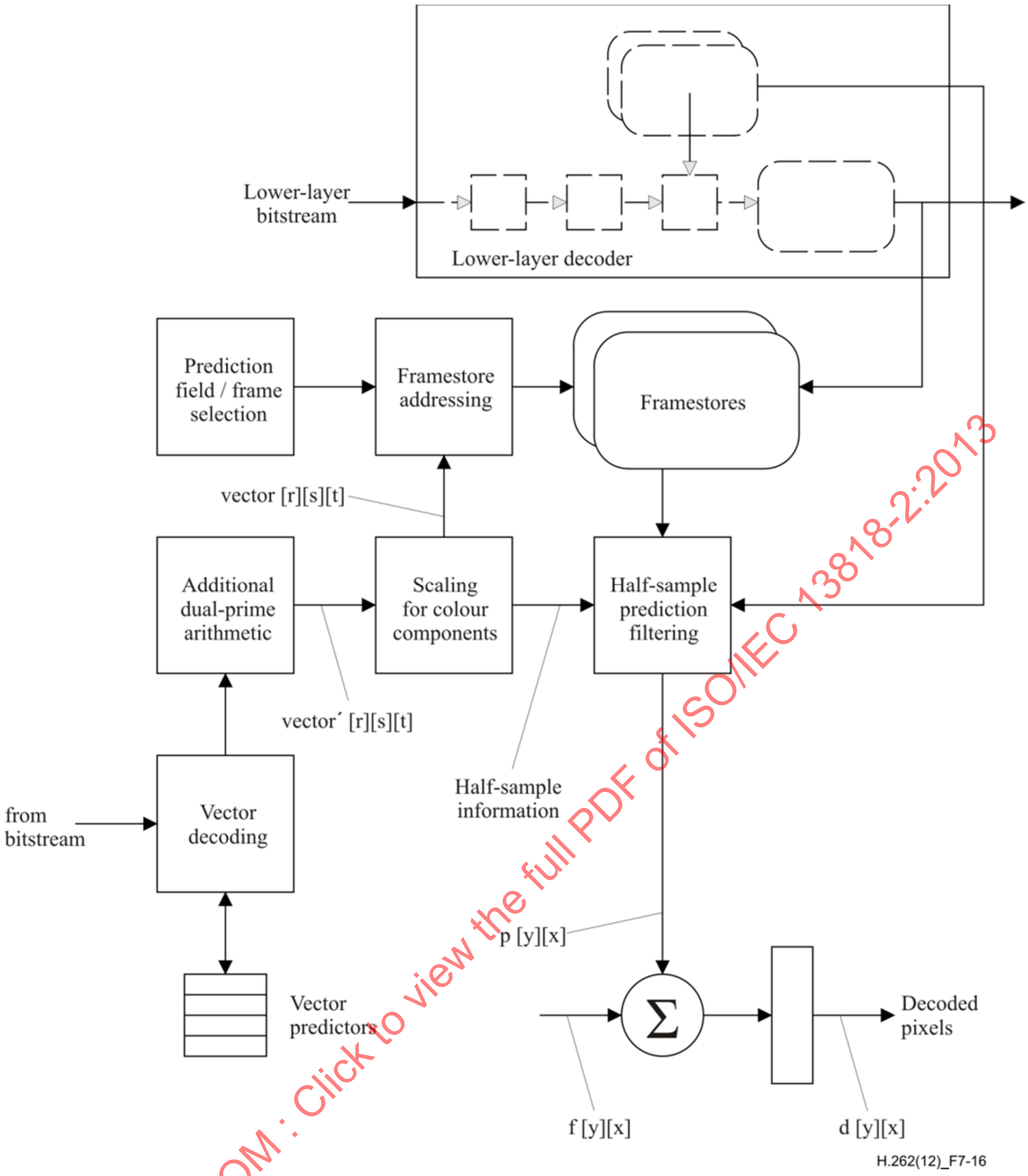


Figure 7-16 – Simplified motion compensation process for the enhancement layer using temporal scalability

GOP header

There is no restriction on GOP header (if present) to be the same as that for lower layer.

Picture header

There is no restriction on picture headers to be the same as in the lower layer.

Picture coding extension

The values in this extension can be different from the lower layer except for top_field_first, concealment_motion_vectors, and chroma_420_type and progressive_frame. The top_field_first shall be based on progressive_sequence and mux_to_progressive_sequence (see sequence_scalable_extension above) and concealment_motion_vectors shall be 0. Chroma_420_type shall be identical to the lower layer. Progressive_frame shall always have the same value as progressive_sequence.

Picture temporal scalable extension

This extension shall be present for each picture.

Quant matrix extension

This extension may be present in the enhancement layer.

7.9.2 Restrictions on temporal prediction

Although temporal predictions can be made from decoded pictures referenced by forward_temporal_reference or both forward_temporal_reference and backward_temporal_references, temporal scalability is efficient if predictions are formed using decoded picture/pictures from lower layer and enhancement layer that are very close in time to the enhancement picture being predicted. It is a requirement on the bitstreams that P-pictures and B-pictures shall form predictions from most recent or next pictures as illustrated by Tables 7-28 and 7-29.

In case group_of_pictures_header occurs very often in lower_layer, ambiguity can occur due to possibility of non-uniqueness of temporal references (which are reset at each group_of_pictures_header). This ambiguity shall be resolved with help of systems layer timing information.

7.10 Data partitioning

Data partitioning is a technique that splits a video bitstream into two layers, called partitions. A priority breakpoint indicates which syntax elements are placed in partition 0, which is the base partition (also called high priority partition). The remainder of the bitstream is placed in partition 1 (which is also called low priority partition). Sequence, GOP, and picture headers are redundantly copied in partition 1 to facilitate error recovery. The sequence_end_code is also redundantly copied into partition 1. All fields in the redundant headers must be identical to the original ones. The only extensions allowed (and required) in partition 1 are sequence_extension(), picture_coding_extension() and sequence_scalable_extension().

NOTE – The slice() syntax given in 6.2.4 is followed in both partitions up to (and including) the syntax element extra_bit_slice.

The interpretation of priority_breakpoint is given in Table 7-30.

Table 7-30 – Priority breakpoint values and associated semantics

priority_break point	Syntax elements included in partition zero
0	This value is reserved for partition 1. All slices in partition 1 shall have a priority_breakpoint equal to 0.
1	All data at the sequence, GOP, picture and slice() down to **extra_bit_slice** in slice().
2	All data included above, plus macroblock syntax elements up to and including **macroblock_address_increment**.
3	All data included above, plus macroblock syntax elements up to but not including coded_block_pattern().
4 … 63	Reserved.
64	All syntax elements up to and including coded_block_pattern() or DC coefficient (**dct_dc_differential**), and the first (run, level) DCT coefficient pair (or EOB). (Note)
65	All syntax elements above, plus up to 2 (run, level) DCT coefficient pairs.
…	
63 + j	All syntax elements above, plus up to j (run, level) DCT coefficient pairs.
…	
127	All syntax elements above, plus up to 64 (run, level) DCT coefficient pairs.
NOTE – A priority_breakpoint immediately following the DC coefficient is disallowed since it might cause start code emulation.	

Semantics of VBV remains unchanged, i.e. the VBV refers to the sum of two partitions, not any single one.

The bitstream parameters bit_rate (bit_rate_value and bit_rate_extension), vbv_buffer_size (vbv_buffer_size_value and vbv_buffer_size_extension) and vbv_delay shall take the same value in the two partitions. These parameters refer to the characteristics of the entire bitstream formed from the two partitions.

The decoding process is modified in the following manner:

– Set current_partition to 0, and start decoding from bitstream that contains the sequence_scalable_extension (partition 0).
– If current_partition = 0, check to see if the current point in the bitstream is a priority breakpoint.

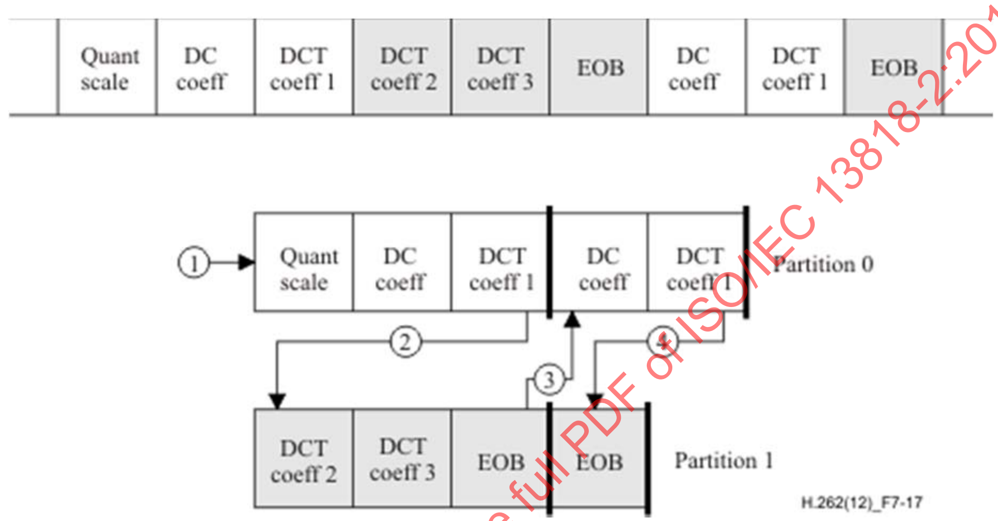
  If yes, set current_partition to 1. Next item will be decoded from partition 1.

  Otherwise, continue decoding from partition 0. Remove sequence, GOP, and picture headers from both partitions.
– If current_partition = 1, check the priority breakpoint to see if the next item to be decoded is expected in partition 0.

  If yes, set current_partition to 0. Next item will be decoded from partition 0.

  Otherwise, continue decoding from partition 1.

An example is shown in Figure 7-17 where the priority breakpoint is set at 64 [one (run, level) pair].



The two partitions are shown, with arrows indicating how the decoder needs to switch between partitions.

Figure 7-17 – A segment from a bitstream with two partitions, with priority_breakpoint set to 64 (one (run, level) pair)

7.11 Hybrid scalability

Hybrid scalability is the combination of two different types of scalability. The types of scalability that can be combined are SNR scalability, spatial scalability and temporal scalability. When two types of scalability are combined, there are three bitstreams that have to be decoded. The layers to which these bitstreams belong are named in Table 7-31.

Table 7-31 – Names of layers

layer_id	Name
0	Base layer
1	Enhancement layer 1
2	Enhancement layer 2
…	…

For the scalability between the enhancement layers 1 and 2, the enhancement layer 1 is its lower layer, and the enhancement layer 2 is its enhancement layer. No layer can be omitted from the hierarchical ladder. E.g. if there is SNR scalability between enhancement layer 1 and enhancement layer 2, the prediction types in enhancement layer 1 are also valid for the combined decoding process for enhancement layers 1 and 2.

The coupling of layers is more loose with spatial and temporal scalability than with SNR scalability. Therefore, in these kinds of scalability, first the base layer has to be decoded and upconverted before it can be used in the enhancement layer. In SNR scalability, both layers are decoded simultaneously. The decoding order can be summarised as follows:

Case 1

base layer

<spatial or temporal scalability>

enhancement layer 1

<SNR scalability>

enhancement layer 2

First decode the base layer, and then decode both enhancement layers simultaneously.

Case 2

base layer

<SNR scalability>

enhancement layer 1

<spatial or temporal scalability>

enhancement layer 2

First decode the base layer and the enhancement layer 1 simultaneously, and then decode the enhancement layer 2.

Case 3

base layer

<spatial or temporal scalability>

enhancement layer 1

<spatial or temporal scalability>

enhancement layer 2

First decode the base layer, then decode the enhancement layer 1, and finally decode enhancement layer 2.

7.12 Output of the decoding process

This subclause describes the output of the theoretical model of the decoding process that decodes bitstreams conforming to this Specification.

The decoding process input is one or more coded video bitstreams (one for each of the layers). The video layers are generally multiplexed by means of a system stream that also contains timing information.

The output of the decoding process is a series of fields or frames that are normally the input of a display process. The order in which fields or frames are output by the decoding process is called the display order, and may be different from the coded order (when B-pictures are used). The display process is responsible for the action of displaying the decoded fields or frames on a display device. If the display device cannot display at the frame rate indicated in the bitstream, the display process may perform frame rate conversion. This Specification does not describe a theoretical model of display process nor the operation of the display process.

Since some of the syntax elements, such as progressive_frame, may be needed by the display process, in this theoretical model of the decoding process, all the syntactic elements that are decoded by the decoding process are output by the decoding process and may be accessed by the display process.

When the progressive sequence is decoded (progressive_sequence is equal to 1), the luminance and chrominance samples of the reconstructed frames are output by decoding process in the form of progressive frames and the output rate is the frame rate. Figure 7-18 illustrates this in the case of chroma_format equals to 4:2:0.

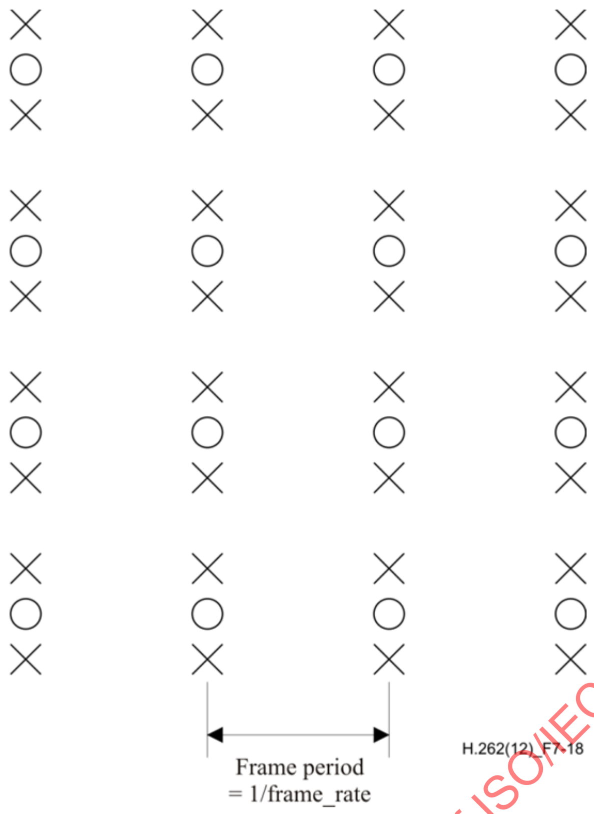


Figure 7-18 – progressive_sequence == 1

The same reconstructed frame is output one time if repeat_first_field is equal to 0, and two or three consecutive times if repeat_first_field is equal to 1, depending on the value of top_field_first. Figure 7-19 illustrates this in the case of chroma_format equals to 4:2:0 and repeat_first_field equals 1.

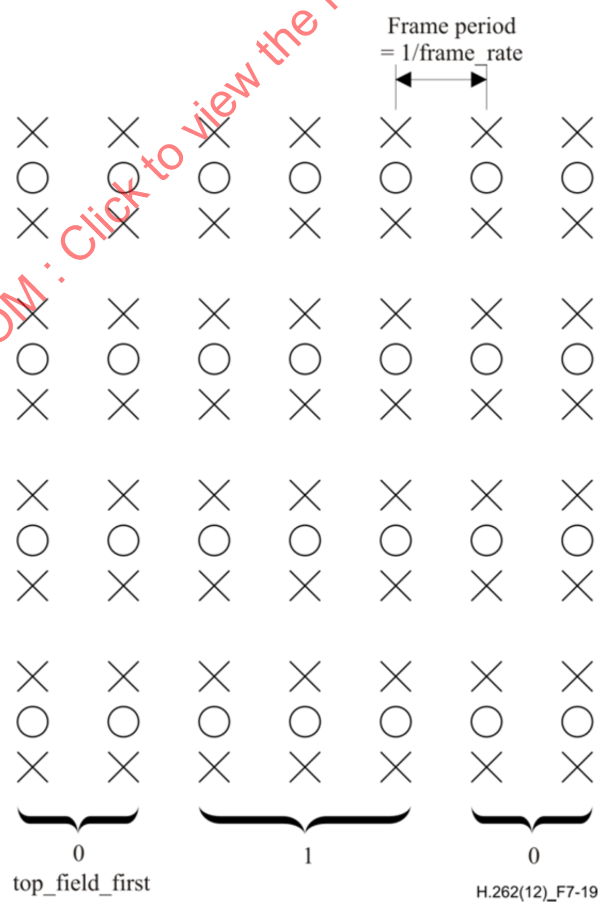


Figure 7-19 – progressive_sequence=='1'; repeat_first_field=='1'

When decoding an interlaced sequence (progressive_sequence is equal to 0), the luminance samples of the reconstructed frames are output by the decoding process in the form of interlaced fields at a rate that is twice the frame rate. Figure 7-20 illustrates this.

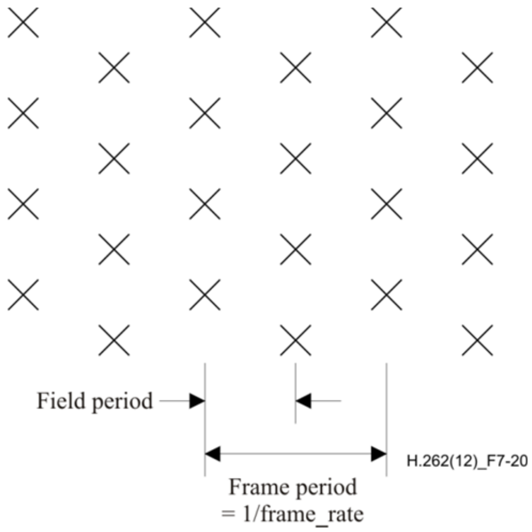


Figure 7-20 – progressive_sequence == 0

It is a requirement on the bitstream that the fields at the output of the decoding process shall always be alternately top and bottom (note that the very first field of a sequence may be either top or bottom).

If the reconstructed frame is interlaced (progressive_frame is equal to 0), the luminance samples and chrominance samples are output by the decoding process in the form of two consecutive fields. The first field output by the decoding process is the top field or the bottom field of the reconstructed frame, depending on the value of top_field_first.

Although all the samples of progressive frames represent the same instant in time, all the samples are not output at the same time by the decoding process when the sequence is interlaced.

If the reconstructed frame is progressive (progressive_frame is equal to 1), the luminance samples are output by the decoding process in the form of two or three consecutive fields, depending on the value of repeat_first_field.

NOTE – The information that these fields originate from the same progressive frame in the bitstream is conveyed to the display process.

All of the chrominance samples of the reconstructed progressive frame are output by the decoding process at the same time as the first field of luminance samples. This is illustrated in Figures 7-21 and 7-22.

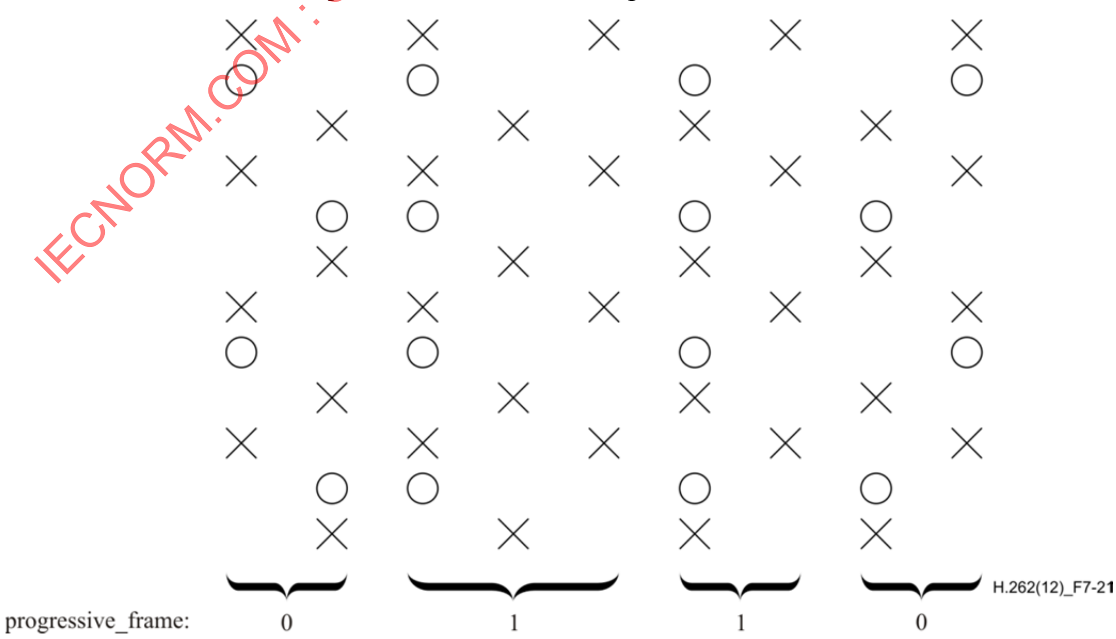


Figure 7-21 – progressive_sequence == 0 with 4:2:0 chrominance

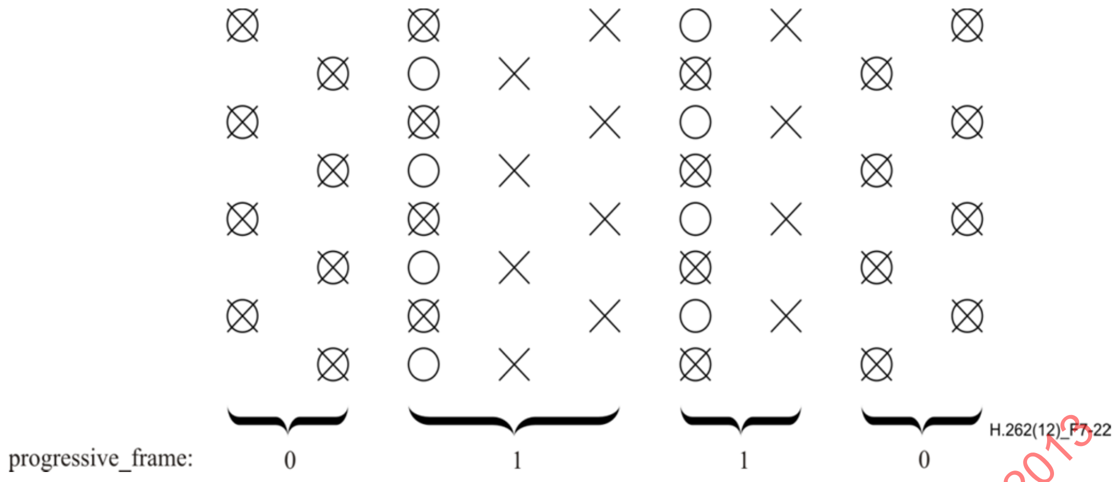


Figure 7-22 – progressive_sequence == 0 with 4:2:2 or 4:4:4 chrominance

8 Profiles and levels

NOTE – In this Specification the word "profile" is used as defined below. It should not be confused with other definitions of "profile" and in particular it does not have the meaning that is defined by ISO/IEC JTC1/Special Group on Functional Standardization.

Profiles and levels provide a means of defining subsets of the syntax and semantics of this Specification and thereby the decoder capabilities required to decode a particular bitstream. A profile is a defined subset of the entire bitstream syntax that is defined by this Specification. A level is a defined set of constraints imposed on parameters in the bitstream. Conformance tests will be carried out against defined profiles at defined levels.

The purpose of defining conformance points in the form of profiles and levels is to facilitate bitstream interchange among different applications. Implementers of this Specification are encouraged to produce decoders and bitstreams which correspond to those defined conformance regions. The discretely defined profiles and levels are the means of bitstream interchange between applications of this Specification.

In this clause the constrained parts of the defined profiles and levels are described. All syntactic elements and parameter values which are not explicitly constrained may take any of the possible values that are allowed by this Specification. In general, a decoder shall be deemed to be conformant to a given profile at a given level if it is able to properly decode all allowed values of all syntactic elements as specified by that profile at that level. One exception to this rule exists in the case of a Simple profile Main level decoder, which must also be able to decode Main profile, Low level bitstreams. A bitstream shall be deemed to be conformant if it does not exceed the allowed range of allowed values and does not include disallowed syntactic elements.

Attention is drawn to 5.4 which defines the convention for specifying a range of numbers. This is used throughout to specify the range of values and parameters.

The profile_and_level_indication in the sequence_extension indicates the profile and level to which the bitstream complies. The most significant bit of profile_and_level_indication is called 'escape bit'. When the escape bit is set to zero, the profile and level are derived from profile_and_level_indication according to Tables 8-1, 8-2 and 8-3.

Table 8-1 – Meaning of bits in profile_and_level_indication

Bits	Field Size (bits)	Meaning
[7:7]	1	Escape bit
[6:4]	3	Profile identification
[3:0]	4	Level identification

Table 8-2 specifies the profile identification codes and Table 8-3 the level identification codes. When the escape bit equals zero a profile with a numerically larger identification value will be a subset of a profile with a numerically smaller identification value. Similarly, whenever the escape bit equals zero, a level with a numerically larger identification value will be a subset of a level with a numerically smaller identification value.

Table 8-2 – Profile identification

Profile identification	Profile
110 to 111	(Reserved)
101	Simple
100	Main
011	SNR Scalable
010	Spatially Scalable
001	High
000	(Reserved)

Table 8-3 – Level identification

Level identification	Level
1011 to 1111	(Reserved)
1010	Low
1001	(Reserved)
1000	Main
0111	(Reserved)
0110	High 1440
0101	(Reserved)
0100	High
0011	(Reserved)
0010	HighP
0000 and 0001	(Reserved)

Table 8-4 describes profiles and levels when the escape bit equals 1. For these profiles and levels there is no implied hierarchy from the assignment of profile_and_level_indication and profiles and levels are not necessarily subsets of others.

Attention is drawn to Annex E, which describes in detail those parts of ISO/IEC 13818-2 that are used for a given profile and level.

NOTE 1 – On 4:2:2 Profile: The Rec. ITU-T H.262 | ISO/IEC 13818-2 compression algorithm exploits temporal redundancy, spatial redundancy, and human psycho-visual properties and is not a lossless algorithm. For sequences with substantial spatial and temporal redundancies, or without many sharp lines/edges, the quality of the sequences obtained after decompression will be higher than that obtained for sequences with lower redundancy, or with a large number of sharp lines/edges.

The 4:2:2 profile can provide higher video quality, better chroma resolution and allows a higher bit rate (at Main level, up to 50 Mbit/s) than MP@ML. It also provides the capability to encode all active lines of video.

Although it is not part of the hierarchy of profiles and levels, the 4:2:2 profile @ Main level decoder is required to decode all the bit streams decodable by MP@ML decoders.

The 4:2:2 profile does not support scalability. This allows implementation architectures to be similar to those of MP@ML.

This profile can be used for applications requiring multiple generations of encoding and decoding. In the case of multiple generations without picture manipulation or change in picture coding type between generations, the quality remains nearly constant after the first generation. Use of picture manipulation or change in picture coding type between generations causes some degradation in quality. Nevertheless, the resulting quality is acceptable for a broad range of applications.

The 4:2:2 profile permits all I-picture encoding. This enables fast recovery from transmission errors and can simplify editing applications. This profile allows the high bit rates required to maintain high quality while using only I-picture coding. The 4:2:2 profile also allows the use of P- and B-picture coding types which can further improve quality or reduce bit rate for the same quality.

See Annex J for more information on the picture quality of the 4:2:2 profile.

NOTE 2 – On Multi-view Profile: The Multi-view Profile (MVP) is envisioned to be a profile appropriate for applications that require multiple viewpoints within the context of Rec. ITU-T H.262 | ISO/IEC 13818-2. MVP supports stereoscopic pictures as its source images for a wide range of picture resolution and quality as requested by the applications to be used. A base layer of MVP is assigned to a left view and an enhancement layer is assigned to a right view.

Table 8-4 – Escape profile_and_level_indication identification

profile_and_level_indication	Name
10001111 to 11111111	(Reserved)
10001110	Multi-view profile @ Low level
10001101	Multi-view profile @ Main level
10001100	(Reserved)
10001011	Multi-view profile @ High1440 level
10001010	Multi-view profile @ High level
10000110 to 10001001	(Reserved)
10000101	4:2:2 profile @ Main level
10000011 to 10000100	(Reserved)
10000010	4:2:2 profile @ High level
10000000 to 10000001	(Reserved)

A monoscopic coding with the same tools as Main Profile (MP), including ISO/IEC 11172-2, is applied to the base layer. An enhancement layer is coded using Temporal Scalability tools and a hybrid prediction of motions and disparity can be utilized in the enhanced layer.

MVP, viewed as one of the scalable profiles in terms of multiple viewpoint layers, is expected to have the same type of compatibility features other scalable profiles have, such as compatibility with MP. For example:

1) decoders compliant to MVP at a certain Level are capable of decoding the bitstreams compliant to MP at the corresponding Level (i.e. forward compatibility);
2) decoders compliant to MP at a certain Level are capable of decoding the bitstream in the base layer of MVP (i.e. backward compatibility).

8.1 ISO/IEC 11172-2 compatibility

ISO/IEC 11172-2 "constrained parameter" bitstreams shall be decodable by Simple, Main, SNR Scalable, Spatially Scalable and High profile decoders at all levels. Additionally Simple, Main, SNR Scalable, Spatially Scalable and High profile decoders shall be able to decode D-pictures-only bitstreams of ISO/IEC 11172-2 which are within the level constraints of the decoder.

8.2 Relationship between defined profiles

The Simple, Main, SNR Scalable, Spatially Scalable and High profiles have a hierarchical relationship. Therefore the syntax supported by a 'higher' profile includes all the syntactic elements of 'lower' profiles (e.g. for a given level, a Main profile decoder shall be able to decode a bitstream conforming to Simple profile restrictions). For a given profile, the same syntax set is supported regardless of level. The order of hierarchy is given in Table 8-2.

The syntactic differences between constraints of profiles are given in Table 8-5. This table describes the limits which apply to a bitstream. Note that a Simple Profile conformant decoder must be able to fully decode both Simple profile, Main level and Main profile, Low level bitstreams.

Table 8-5 – Syntactic constraints of profiles

Syntactic Element	Profile						
	Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
chroma_format	4:2:0	4:2:0	4:2:0	4:2:0	4:2:2 or 4:2:0	4:2:2 or 4:2:0	4:2:0
frame_rate_extension_n	0	0	0	0	0	0	0
frame_rate_extension_d	0	0	0	0	0	0	0
aspect_ratio_information	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011	0001, 0010, 0011
picture_coding_type	I, P	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B	I, P, B
repeat_first_field	Constrained		Unconstrained			Constrained	Unconstrained
sequence_scalable_ extension()	No	No	Yes	Yes	Yes	No	Yes
scalable_mode	–	–	SNR	SNR or Spatial	SNR or Spatial	–	Temporal
picture_spatial_scalable_ extension()	No	No	No	Yes	Yes	No	No
picture_temporal_scalable _ extension()	No	No	No	No	No	No	Yes
intra_dc_precision	8, 9, 10	8, 9, 10	8, 9, 10	8, 9, 10	8, 9, 10, 11	8, 9, 10, 11	8, 9, 10
Slice structure	Restricted 6.1.2.2						

For all defined profiles, there is a semantic restriction on the bitstream that all of the data for a macroblock shall be represented with not more than the number of bits indicated by Table 8-6. However, a maximum of two macroblocks in each horizontal row of macroblocks may exceed this limitation.

Table 8-6 – Maximum number of bits in a macroblock

chroma_format	Maximum number of bits
4:2:0	4608
4:2:2	6144
4:2:2 (in 4:2:2 Profile)	Unconstrained
4:4:4	9216

In this context, a macroblock is deemed to start with the first bit of the macroblock_address_increment (or macroblock_escape, if any) and continues until the last bit of the macroblock() syntactic structure. The bits required to represent any slice() that precedes (or follows) the macroblock are not counted as part of the macroblock.

The High profile is also distinguished by having different constraints on luminance sample rate, maximum bit rate, and VBV buffer size. Refer to Tables 8-12, 8-13 and 8-14.

Decoders that are Simple profile @ Main level compliant shall be capable of decoding Main profile @ Low level bitstreams.

8.2.1 Use of repeat_first_field

The use of repeat_first_field in Simple and Main profile bitstreams is constrained as specified in Table 8-7.

Table 8-7 – Constraints on use of repeat_first_field for Simple and Main Profiles

frame_rate_code	frame_rate_value	**Repeat_first_field**	
		progressive_ sequence==0	**progressive_ sequence==1**
0000	Forbidden		
0001	24 000 ÷ 1001 (23.976…)	0	0
0010	24	0	0
0011	25	0 or 1	0
0100	30 000 ÷ 1001 (29.97…)	0 or 1	0
0101	30	0 or 1	0
0110	50	0 or 1	0
0111	60 000 ÷ 1001 (59.94…)	0 or 1	0 or 1
1000	60	0 or 1	0 or 1
…	Reserved		
1111	Reserved		

Additional constraints exist for Main profile @ Main level and Simple profile @ Main level only:

- if (vertical_size > 480 lines) or (frame_rate is "25Hz") then if picture_coding_type == 011 (i.e. B-picture), repeat_first_field shall be 0.
- if vertical_size > 480 lines frame_rate shall be "25Hz"

Additionally, the following constraints exist for 4:2:2 profile @ Main level only:

- if vertical_size > 512 lines,
  then if picture_coding_type=011 (i.e. B-picture), repeat_first_field shall be 0;
- if vertical_size > 512 lines frame_rate shall be "25Hz".

8.3 Relationship between defined levels

The Low, Main, High-1440, High and HighP levels have a hierarchical relationship. Therefore the parameter constraints of a 'higher' level equal or exceed the constraints of 'lower' levels (e.g. for a given profile, a Main level decoder shall be able to decode a bitstream conforming to Low level restrictions). The order of hierarchy is given in Table 8-3.

The different parameter constraints for levels are given in Table 8-8.

8.4 Scalable layers

The SNR Scalable, Spatial Scalable, High and Multi-view profiles may use more than one bitstream to code the image. These different bitstreams represent layers of coding, which when combined create a higher quality image than that obtainable from one layer alone (see Annex F). The maximum number of layers for a given profile is specified in Table 8-9. The scalable layers are named according to Table 7-31. The syntactic and parameter constraints for these profile/level combinations when coded using the maximum permitted number of layers are given in Tables 8-11, 8-12, 8-13 and 8-14. When the number of layers is less than the maximum permitted, reference should also be made to Tables E-21 to E-46 as appropriate.

It should be noted that a bitstream of the base layer of SNR Scalable and Multi-view profiles can always be decoded by a Main profile decoder of equivalent level. Conversely, a Main profile bitstream shall be decodable by either SNR Scalable or Multi-view profile decoder of equivalent level.

Table 8-8 – Parameter constraints for levels

Syntactic Element	Level				
	Low	**Main**	**High-1440**	**High**	**HighP**
f_code[0][0] (forward horizontal)	[1:7]	[1:8]	[1:9]	[1:9]	[1:9]
f_code[1][0][a)] (backward horizontal)	[1:7]	[1:8]	[1:9]	[1:9]	[1:9]
frame_rate_code	[1:5]	[1:5]	[1:8]	[1:8]	[1:8]
picture_structure	'01', '10', '11'	'01', '10', '11'	'01', '10', '11'	'01', '10', '11'	'11'
frame_pred_frame_dct	[0:1]	[0:1]	[0:1]	[0:1]	1
Sample Density	Table 8-11				
Luminance Sample Rate	Table 8-12				
Maximum Bit Rate	Table 8-13				
Buffer Size	Table 8-14				
Frame picture					
f_code[0][1] (forward vertical)	[1:4]	[1:5]	[1:5]	[1:5]	[1:5]
f_code[1][1][a)] (backward vertical)	[1:4]	[1:5]	[1:5]	[1:5]	[1:5]
Vertical vector range[b)]	[–64:63.5]	[–128:127.5]	[–128:127.5]	[–128:127.5]	[–128:127.5]
Field picture					
f_code[0][1] (forward vertical)	[1:3]	[1:4]	[1:4]	[1:4]	NA[c)]
f_code[1][1][a)] (backward vertical)	[1:3]	[1:4]	[1:4]	[1:4]	NA[c)]
Vertical vector range[b)]	[–32:31.5]	[–64:63.5]	[–64:63.5]	[–64:63.5]	NA[c)]

a) For Simple profile bitstreams which do not include B-pictures, f_code[1][0] and f_code[1][1] shall be set to 15 (not used).

b) This restriction applies to the final reconstructed motion vector. In the case of dual prime motion vectors, this restriction applies to all the following values:

vector'[0][0][1]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2)
((vector'[0][0][1] * m[parity_ref][parity_pred])//2) + e[parity_ref][parity_pred]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2) + dmvector[1]
((vector'[0][0][1] * m[parity_ref][parity_pred])//2) + e[parity_ref][parity_pred] + dmvector[1]

c) In this table, 'NA' indicates a constraint that does not apply due to a constraint on the value of picture_structure.

Table 8-9 – Upper bounds for scalable layers in SNR Scalable, Spatial Scalable, High and Multi-view profiles

Level	Maximum Number of	Profile			
		SNR	Spatial	High	Multi-view
High	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers			3 1 1 0	2 0 0 1
High-1440	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers		3 1 1 0	3 1 1 0	2 0 0 1
Main	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers	2 0 1 0		3 1 1 0	2 0 0 1
Low	All layers (base + enhancement) Spatial enhancement layers SNR enhancement layers Temporal auxiliary layers	2 0 1 0			2 0 0 1

8.4.1 Permissible layer combinations

Table 8-10 is a summary of the permitted combinations, and is subject to the following rules:

- SNR Scalable and Multi-view profile: maximum of 2 layers; Spatial Scalable and High profile: maximum of 3 layers. (See Table 8-9.)
- Only one SNR and one Spatial scale allowed in 3-layer combinations, either SNR/Spatial or Spatial/SNR order is permitted. (See Table 8-9.)
- Chroma simulcast, which allows to add 4:2:2 chroma information to a 4:2:0 base layer and defined in 7.8 is implemented with SNR scalability.
- A 4:2:0 layer is not permitted if the lower layer is 4:2:2. (See 7.7.3.3.)
- (level – 1) is defined as follows:
  - if level is Main, (level – 1) is Low;
  - if level is High – 1440, (level – 1) is Main;
  - if level is High, (level – 1) is High – 1440.

Table 8-10 – Permissible layer combinations

	Scalable mode			Profile/level of simplest base layer decoder (level reference top layer) [a]
Profile	Base layer	Enhancement layer 1	Enhancement layer 2	
SNR	4:2:0	SNR, 4:2:0	–	MP@same level
Spatial	4:2:0	SNR, 4:2:0	–	MP@same level
Spatial	4:2:0	Spatial, 4:2:0	–	MP@(level – 1)
Spatial	4:2:0	SNR, 4:2:0	Spatial, 4:2:0	MP@(level – 1)
Spatial	4:2:0	Spatial, 4:2:0	SNR, 4:2:0	MP@(level – 1)
High	4:2:0	–	–	HP@same level
High	4:2:2	–	–	HP@same level
High	4:2:0	SNR, 4:2:0	–	HP@same level
High	4:2:0	SNR, 4:2:2	–	HP@same level
High	4:2:2	SNR, 4:2:2	–	HP@same level
High	4:2:0	Spatial, 4:2:0	–	HP@(level – 1)
High	4:2:0	Spatial, 4:2:2	–	HP@(level – 1)
High	4:2:2	Spatial, 4:2:2	–	HP@(level – 1) [b]
High	4:2:0	SNR, 4:2:0	Spatial, 4:2:0	HP@(level – 1)
High	4:2:0	SNR, 4:2:0	Spatial, 4:2:2	HP@(level – 1)
High	4:2:0	SNR, 4:2:2	Spatial, 4:2:2	HP@(level – 1) [b]
High	4:2:2	SNR, 4:2:2	Spatial, 4:2:2	HP@(level – 1) [b]
High	4:2:0	Spatial, 4:2:0	SNR, 4:2:0	HP@(level – 1)
High	4:2:0	Spatial, 4:2:0	SNR, 4:2:2	HP@(level – 1)
High	4:2:0	Spatial, 4:2:2	SNR, 4:2:2	HP@(level – 1)
High	4:2:2	Spatial, 4:2:2	SNR, 4:2:2	HP@(level – 1) [b]
Multi-view	4:2:0	Temporal, 4:2:0	–	MP@same level

[a] The simplest compliant decoder to decode the base layer is specified, assuming that bitstream may contain any syntax and parameter value permitted for the stated profile @ level, except scalability. Note that for High profile @ Main level spatially scaled bitstreams, 'HP @ (level – 1)' becomes 'MP @ (level – 1)'. In the event that a base layer bitstream uses fewer syntactic elements or a reduced parameter range than permitted, profile_and_level_indication may indicate a 'simpler' profile @ level.

[b] Note that 4:2:2 chroma format is not supported as a lower spatial layer of High profile @ Main level (see Table 8-12).

Details of the different parameter limits that may be applied in each layer of a bitstream and the corresponding appropriate profile_and_level_indication that should be used are given in Tables E.21 to E.52.

8.4.2 Multi-view Profile specific constraints

Both the enhancement and base layers have the same frame rate.

The picture_mux_enable, picture_mux_order and picture_mux_factor are not used in this profile and shall be ignored.

The reference_select_code should be "00" or "01" for the P-frames in the enhancement layer. The reference_select_code should be "01" for B-frames in the enhancement layer.

If the base layer coded frame is the first frame of the Group Of Pictures, then the corresponding frame in the enhancement layer should be either I-frame or P-frame with the reference_select_code value of "01".

In a P-field picture with reference_select_code = "01" and which is the first field of a frame, the following restriction applies:

- Dual prime prediction shall not be used.
- Field prediction in which motion_vertical_field_select indicates the second field of the base layer frame shall not be used.
- If base and enhancement layers do not have the same value for top_field_first, there shall be no macroblocks that are coded with macroblock_motion_forward zero and macroblock_intra zero.
- If base and enhancement layer do not have the same value for top_field_first, there shall be no skipped macroblocks.

In a B-field picture which is the first field of a frame, the prediction shall not make reference to the second field of the corresponding base layer frame.

It is inherent in the Multi-view Profile that the two layers are tightly coupled to one another. It is a requirement that the pictures in enhancement layer shall be decoded immediately after their corresponding required reference pictures are decoded unless this requirement makes one to decode the enhancement layer pictures out of display order. In that case, the pictures in the enhancement layer should be decoded in the display order.

8.5 Parameter values for defined profiles, levels and layers

See Table 8-11.

Table 8-11 - Upper bounds for sampling density

Level	Spatial resolution layer		Profile						
			Simple	Main	SNR	Spatial	High	4:2:2	Multi
HighP	Enhancement	Samples/line Lines/frame Frames/sec		1920 1088 60					
	Lower	Samples/line Lines/frame Frames/sec		–					
High	Enhancement	Samples/line Lines/frame Frames/sec		1920 1088 60			1920 1088 60	1920 1088 60	1920 1088 60
	Lower	Samples/line Lines/frame Frames/sec		–			960 576 30	–	1920 1088 60
High-1440	Enhancement	Samples/line Lines/frame Frames/sec		1440 1088 60		1440 1088 60	1440 1088 60	–	1440 1088 60
	Lower	Samples/line Lines/frame Frames/sec		–		720 576 30	720 576 30	–	1440 1088 60
Main	Enhancement	Samples/line Lines/frame Frames/sec	720 576 30	720 576 30	720 576 30		720 576 30	720 608 a) 30	720 576 30
	Lower	Samples/line Lines/frame Frames/sec	–	–	–		352 288 30	–	720 576 30
Low	Enhancement	Samples/line Lines/frame Frames/sec		352 288 30	352 288 30			–	352 288 30
	Lower	Samples/line Lines/frame Frames/sec		–	–			–	352 288 30

In the case of single layer or SNR scaled coding, the limits specified by 'Enhancement layer' apply.

a) 512 lines/frame for 525/60, 608 lines/frame for 625/50

The syntactic elements referenced by this table are as follows:

- samples/line: horizontal_size;
- lines/frame: vertical_size;
- frames/sec: frame_rate.

The upper bound for frame_rate is the same for both progressive_sequence == 0 and progressive_sequence == 1.

Table 8-12 – Upper bounds for luminance sample rate (samples/s)

Level	Spatial resolution layer	Profile						
		Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
HighP	Enhancement		125 337 600				–	
	Lower		–				–	
High	Enhancement		62 668 800			62 668 800 (4:2:2) 83 558 400 (4:2:0)	62 668 800	62 668 800
	Lower		–			14 745 600 (4:2:2) 19 660 800 (4:2:0)	–	62 668 800
High-1440	Enhancement		47 001 600		47 001 600	47 001 600 (4:2:2) 62 668 800 (4:2:0)	–	47 001 600
	Lower		–		10 368 000	11 059 200 (4:2:2) 14 745 600 (4:2:0)	–	47 001 600
Main	Enhancement	10 368 000	10 368 000	10 368 000		11 059 200 (4:2:2) 14 745 600 (4:2:0)	11 059 200	10 368 000
	Lower	–	–	–		– 3 041 280 (4:2:0)	–	10 368 000
Low	Enhancement		3 041 280	3 041 280			–	3 041 280
	Lower		–	–			–	3 041 280
NOTE – In the case of single layer or SNR scaled coding, the limits specified by "Enhancement layer" apply.								

The luminance sample rate P is defined as follows:

– For progressive_sequence == 1:

$$P = (16 * ((horizontal\_size + 15) / 16)) \times (16 * ((vertical\_size + 15) / 16)) \times frame\_rate$$

– For progressive_sequence == 0:

$$P = (16 * ((horizontal\_size + 15) / 16)) \times (32 * ((vertical\_size + 31) / 32)) \times frame\_rate$$

8.6 Compatibility requirements on decoders

Table 8-15 defines the requirements on compatibility for decoders. There is a requirement that a decoder of a profile and level represented by a column in Table 8-15 be capable of decoding correctly all bitstreams with profile and level indication marked by an X in the column. In case of scalable hierarchy of bitstreams, the profile and level indication are that of the upper layer.

NOTE – For Profiles and Levels which obey a hierarchical structure, it is recommended that each layer of the bitstream contain the profile_and_level_indication of the "simplest" decoder which is capable of successfully decoding that layer of the bitstream. In the case where the profile_and_level_indication Escape bit == 0, this will be the numerically largest of the possible valid values of profile_and_level_indication.

Table 8-13 – Upper bounds for bit rates (Mbit/s)

Level	Profile						
	Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
HighP		80					
High		80			100 all layers 80 middle + base layer 25 base layer	300	– 130 both layers 80 base layer
High-1440		60		60 all layers 40 middle + base layers 15 base layer	80 all layers 60 middle + base layers 20 base layer	–	– 100 both layers 60 base layer
Main	15	15	– 15 both layers 10 base layer		20 all layers 15 middle + base layer 4 base layer	50	– 25 both layers 15 base layer
Low		4	– 4 both layers 3 base layer			–	– 8 both layers 4 base layer

NOTE 1 – This table defines the maximum rate of operation of the VBV for a coded bitstream of the given profile and level. This rate is indicated by bit_rate (see 6.3.3).

NOTE 2 – This table defines the maximum permissible data rate for all layers up to and including the stated layer. For multi-layer coding applications, the data rate apportioned between layers is constrained only by the maximum rate permitted for a given layer as stated in this table.

NOTE 3 – 1 Mbit = 1 000 000 bits

Table 8-14 – VBV buffer size requirements (bits)

Level	Layer	Profile						
		Simple	Main	SNR	Spatial	High	4:2:2	Multi-view
HighP	Enhancement 2 Enhancement 1 Base		9 781 248					
High	Enhancement 2 Enhancement 1 Base		9 781 248			12 222 464 9 781 248 3 047 424	47 185 920	– 15 898 480 9 787 248
High-1440	Enhancement 2 Enhancement 1 Base		7 340 032		7 340 032 4 882 432 1 835 008	9 781 248 7 340 032 2 441 216	–	– 12 222 464 7 340 032
Main	Enhancement 2 Enhancement 1 Base	1 835 008	1 835 008	– 1 835 008 1 212 416		2 441 216 1 835 008 475 136	9 437 184	– 3 047 424 1 835 008
Low	Enhancement 2 Enhancement 1 Base		475 136	– 475 136 360 448			–	– 950 272 475 136

NOTE 1 – The buffer size is calculated to be proportional to the maximum allowable bit rate, rounded down to the nearest multiple of 16 × 1024 bits. The reference value for scaling is the Main profile, Main level buffer size.

NOTE 2 – This table defines the total decoder buffer size required to decode all layers up to and including the stated layer. For multi-layer coding applications, the allocation of buffer memory between layers is constrained only by the maximum size permitted for a given layer as stated in this table.

NOTE 3 – The syntactic element corresponding to this table is vbv_buffer_size (see 6.3.3).

Table 8-15 – Forward compatibility between different profiles and levels

Profile and Level indication in bitstream	Decoder																	
	HP @HL	HP @H-14	HP @ML	Spatial @H-14	SNR @ML	SNR @LL	MP @HPL	MP @HL	MP @H-14	MP @ML	MP @LL	SP @ML	4:2:2P @ML	4:2:2P @HL	MVP @HL	MVP @H-14	MVP @ML	MVP @LL
HP@HL	X																	
HP@H-14	X	X																
HP@ML	X	X	X															
Spatial@H-14	X	X		X														
SNR@ML	X	X	X	X	X													
SNR@LL	X	X	X	X	X	X												
MP@HPL							X											
MP@HL	X						X	X						X[c)]	X			
MP@H-14	X	X		X			X	X	X					X[c)]	X	X		
MP@ML	X	X	X	X	X		X	X	X	X			X[b)]	X[c)]	X	X	X	
MP@LL	X	X	X	X	X	X	X	X	X	X	X	X[a)]	X[b)]	X[c)]	X	X	X	X
SP@ML	X	X	X	X	X		X	X	X	X		X	X[b)]	X[c)]	X	X	X	
ISO/IEC 11172-2	X	X	X	X	X	X	X	X	X	X	X	X	X[b)]	X[c)]	X	X	X	X
4:2:2@ML													X	X[c)]				
4:2:2@HL														X				
MVP@HL															X			
MVP@H-14															X	X		
MVP@ML															X	X	X	
MVP@LL															X	X	X	X

X indicates that the decoder shall be able to decode the bit stream, including all relevant lower layers.

a) SP@ML decoders are required to decode MP@LL bitstreams.

b) A 4:2:2 profile@Main level decoder shall be able to decode Main profile@Main level, Main profile@Low level and Simple profile@Main level bitstreams, as well as ISO/IEC 11172-2 constrained system parameter bitstreams.

c) A 4:2:2 profile@High level decoder shall be able to decode 4:2:2P@ML, MP@HL, MP@H-14, MP@ML, MP@LL and SP@ML, as well as ISO/IEC 11172-2 constrained system parameter bitstreams.

9 Registration of copyright identifiers

9.1 General

Parts 1, 2, and 3 of ISO/IEC 13818 provide support for the management of audiovisual works copyrighting. In Rec. ITU-T H.222.0 | ISO/IEC 13818-1 [6] this is by means of a copyright descriptor, while Rec. ITU-T H.262 | ISO/IEC 13818-2 and ISO/IEC 13818-3 [14] contain fields for identifying copyright holders through syntax fields in the elementary stream syntax. This Recommendation | International Standard presents the method of obtaining and registering copyright identifiers in Rec. ITU-T H.262 | ISO/IEC 13818-2.

Rec. ITU-T H.262 | ISO/IEC 13818-2 specifies a unique 32-bit copyright_identifier which is a work type code identifier (such as ISBN, ISSN, ISRC, etc.) carried in the copyright descriptor. The copyright_identifier enables identification of a wide number of Copyright Registration Authorities. Each Copyright Registration Authority may specify a syntax and semantic for identifying the audiovisual works or other copyrighted works within that particular copyright organization through appropriate use of the variable length additional_copyright_info field which contains the copyright number.

In the following subclause and Annexes G, H and I, the benefits and responsibilities of all parties to the registration of copyright_identifier are outlined.

9.2 Implementation of a Registration Authority (RA)

ISO/IEC JTC 1 shall call for nominations for an international organization which will serve as the Registration Authority for the **copyright_identifier** as defined in Rec. ITU-T H.262 | ISO/IEC 13818-2. The selected organization shall serve as the Registration Authority. The so-named Registration Authority shall execute its duties in compliance with Annex H of the JTC 1 Directives. The registered copyright_identifier is hereafter referred to as the Registered Identifier (RID).

Upon selection of the Registration Authority, JTC 1 shall require the creation of a Registration Management Group (RMG) which will review appeals filed by organizations whose request for an RID to be used in conjunction with Rec. ITU-T H.262 | ISO/IEC 13818-2 has been denied by the Registration Authority.

Annexes G, H and I to this Specification provide information on the procedures for registering a unique copyright_identifier.

Annex A

Inverse discrete cosine transform

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

The N × N two-dimensional mathematical real-number inverse discrete cosine transform (IDCT) is defined as:

$$f(x,y) = \frac{2}{N}\sum_{u=0}^{N-1}\sum_{v=0}^{N-1} C(u)C(v)F(u,v)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N}$$

with u, v, x, y = 0, 1, 2, … N – 1

where x, y are spatial coordinates in the sample domain

u, v are coordinates in the transform domain

f(x, y) and F(u, v) are real numbers for each pair of values (x, y) and (u, v)

π is Archimedes' constant 3.141 592 653 589 793 238 462 643 ...

$$C(u), C(v) = \begin{cases} \frac{1}{\sqrt{2}} & \text{for u v} = 0 \\ 1 & \text{otherwise} \end{cases}$$

The N × N two-dimensional mathematical real-number discrete cosine transform (DCT) is defined as:

$$F(u,v) = \frac{2}{N}C(u)C(v)\sum_{x=0}^{N-1}\sum_{y=0}^{N-1} f(x,y)\cos\frac{(2x+1)u\pi}{2N}\cos\frac{(2y+1)v\pi}{2N}$$

where x, y, u, v, f(x, y) and F(u, v) are defined as given above for the IDCT definition.

The definition of the DCT (also called forward DCT) is purely informative. The forward DCT is not used by the decoding process specified in this Specification.

For purposes of this Specification, the value of N shall be considered equal to 8.

The mathematical integer-number IDCT is defined as:

$$f'(x, y) = \text{round}(f(x, y))$$

with f(x, y) produced by the mathematical real-number IDCT as specified above for each value of x and y, where round() denotes rounding to the nearest integer, with half-integer values rounded away from zero. No clamping or saturation is performed.

The IDCT function used in the decoding process for computation of the integer values *f*[*y*][*x*] may use any method of integer approximation of the mathematical integer-number IDCT results f '(x, y), provided that it conforms to all requirements specified in ISO/IEC 23002-1 and its Annexes A and B and has sufficient precision so that significant errors do not occur in the final values of the integers.

NOTE – In addition to the above requirement, it is desirable that the integer output of the IDCT function *f*[*y*][*x*] used in the decoding process additionally produces output that is as close as feasible to the result of the mathematical integer-number IDCT f '(x, y) for input values causing one or more elements f '(x, y) of the output of the mathematical integer-number IDCT to somewhat exceed the range of [–384, 383].

Annex B

Variable length code tables

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

B.1 Macroblock addressing

See Table B.1.

Table B.1 – Variable length codes for macroblock_address_increment

macroblock_address_ increment VLC code	Increment value	**macroblock_address_ increment** VLC code	Increment value
1	1	0000 0101 01	18
011	2	0000 0101 00	19
010	3	0000 0100 11	20
0011	4	0000 0100 10	21
0010	5	0000 0100 011	22
0001 1	6	0000 0100 010	23
0001 0	7	0000 0100 001	24
0000 111	8	0000 0100 000	25
0000 110	9	0000 0011 111	26
0000 1011	10	0000 0011 110	27
0000 1010	11	0000 0011 101	28
0000 1001	12	0000 0011 100	29
0000 1000	13	0000 0011 011	30
0000 0111	14	0000 0011 010	31
0000 0110	15	0000 0011 001	32
0000 0101 11	16	0000 0011 000	33
0000 0101 10	17	0000 0001 000	macroblock_escape

NOTE – The "macroblock stuffing" entry that is available in ISO/IEC 11172-2 is not available in this Specification.

B.2 Macroblock type

The properties of the macroblock are determined by the macroblock type VLC according to Tables B.2 to B.8.

Table B.2 – Variable length codes for macroblock_type in I-pictures

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
1	0	0	0	0	1	0	Intra	0
01	1	0	0	0	1	0	Intra, Quant	0

Table B.3 – Variable length codes for macroblock_type in P-pictures

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
1	0	1	0	1	0	0	MC, Coded	0
01	0	0	0	1	0	0	No MC, Coded	0
001	0	1	0	0	0	0	MC, Not Coded	0
0001 1	0	0	0	0	1	0	Intra	0
0001 0	1	1	0	1	0	0	MC, Coded, Quant	0
0000 1	1	0	0	1	0	0	No MC, Coded, Quant	0
0000 01	1	0	0	0	1	0	Intra, Quant	0

Table B.4 – Variable length codes for macroblock_type in B-pictures

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
10	0	1	1	0	0	0	Interp, Not Coded	0
11	0	1	1	1	0	0	Interp, Coded	0
010	0	0	1	0	0	0	Bwd, Not Coded	0
011	0	0	1	1	0	0	Bwd, Coded	0
0010	0	1	0	0	0	0	Fwd, Not Coded	0
0011	0	1	0	1	0	0	Fwd, Coded	0
0001 1	0	0	0	0	1	0	Intra	0
0001 0	1	1	1	1	0	0	Interp, Coded, Quant	0
0000 11	1	1	0	1	0	0	Fwd, Coded, Quant	0
0000 10	1	0	1	1	0	0	Bwd, Coded, Quant	0
0000 01	1	0	0	0	1	0	Intra, Quant	0

Table B.5 – Variable length codes for macroblock_type in I-pictures with spatial scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
1	0	0	0	1	0	0	Coded, Compatible	4
01	1	0	0	1	0	0	Coded, Compatible, Quant	4
0011	0	0	0	0	1	0	Intra	0
0010	1	0	0	0	1	0	Intra, Quant	0
0001	0	0	0	0	0	0	Not Coded, Compatible	4

Table B.6 – Variable length codes for macroblock_type in P-pictures with spatial scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
10	0	1	0	1	0	0	MC, Coded	0
011	0	1	0	1	0	1	MC, Coded, Compatible	1,2,3
0000 100	0	0	0	1	0	0	No MC, Coded	0
0001 11	0	0	0	1	0	1	No MC, Coded, Compatible	1,2,3
0010	0	1	0	0	0	0	MC, Not Coded	0
0000 111	0	0	0	0	1	0	Intra	0
0011	0	1	0	0	0	1	MC, Not coded, Compatible	1,2,3
010	1	1	0	1	0	0	MC, Coded, Quant	0
0001 00	1	0	0	1	0	0	No MC, Coded, Quant	0
0000 110	1	0	0	0	1	0	Intra, Quant	0
11	1	1	0	1	0	1	MC, Coded, Compatible, Quant	1,2,3
0001 01	1	0	0	1	0	1	No MC, Coded, Compatible,Quant	1,2,3
0001 10	0	0	0	0	0	1	No MC, Not Coded, Compatible	1,2,3
0000 101	0	0	0	1	0	0	Coded, Compatible	4
0000 010	1	0	0	1	0	0	Coded, Compatible, Quant	4
0000 011	0	0	0	0	0	0	Not Coded, Compatible	4

Table B.7 – Variable length codes for macroblock_type in B-pictures with spatial scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
10	0	1	1	0	0	0	Interp, Not coded	0
11	0	1	1	1	0	0	Interp, Coded	0
010	0	0	1	0	0	0	Back, Not coded	0
011	0	0	1	1	0	0	Back, Coded	0
0010	0	1	0	0	0	0	For, Not coded	0
0011	0	1	0	1	0	0	For, Coded	0
0001 10	0	0	1	0	0	1	Back, Not Coded, Compatible	1,2,3
0001 11	0	0	1	1	0	1	Back, Coded, Compatible	1,2,3
0001 00	0	1	0	0	0	1	For, Not Coded, Compatible	1,2,3
0001 01	0	1	0	1	0	1	For, Coded, Compatible	1,2,3
0000 110	0	0	0	0	1	0	Intra	0
0000 111	1	1	1	1	0	0	Interp, Coded, Quant	0
0000 100	1	1	0	1	0	0	For, Coded, Quant	0
0000 101	1	0	1	1	0	0	Back, Coded, Quant	0
0000 0100	1	0	0	0	1	0	Intra, Quant	0
0000 0101	1	1	0	1	0	1	For, Coded, Compatible, Quant	1,2,3
0000 0110 0	1	0	1	1	0	1	Back, Coded, Compatible, Quant	1,2,3
0000 0111 0	0	0	0	0	0	0	Not Coded, Compatible	4
0000 0110 1	1	0	0	1	0	0	Coded, Compatible, Quant	4
0000 0111 1	0	0	0	1	0	0	Coded, Compatible	4

Table B.8 – Variable length codes for macroblock_type in I-pictures, P-pictures and B-pictures with SNR scalability

macroblock_type VLC code	macroblock_quant	macroblock_motion_forward	macroblock_motion_backward	macroblock_pattern	macroblock_intra	spatial_temporal_weight_code_flag	Description	permitted spatial_temporal_weight_classes
1	0	0	0	1	0	0	Coded	0
01	1	0	0	1	0	0	Coded, Quant	0
001	0	0	0	0	0	0	Not Coded	0

NOTE – There is no differentiation between picture types, since macroblocks are processed identically in I-, P- and B-pictures. The "Not coded" type is needed, since skipped macroblocks are not allowed at beginning and end of a slice.

B.3 Macroblock pattern

See Table B.9.

Table B.9 – Variable length codes for coded_block_pattern

coded_block_pattern VLC code	cbp	**coded_block_pattern** VLC code	cbp
111	60	0001 1100	35
1101	4	0001 1011	13
1100	8	0001 1010	49
1011	16	0001 1001	21
1010	32	0001 1000	41
1001 1	12	0001 0111	14
1001 0	48	0001 0110	50
1000 1	20	0001 0101	22
1000 0	40	0001 0100	42
0111 1	28	0001 0011	15
0111 0	44	0001 0010	51
0110 1	52	0001 0001	23
0110 0	56	0001 0000	43
0101 1	1	0000 1111	25
0101 0	61	0000 1110	37
0100 1	2	0000 1101	26
0100 0	62	0000 1100	38
0011 11	24	0000 1011	29
0011 10	36	0000 1010	45
0011 01	3	0000 1001	53
0011 00	63	0000 1000	57
0010 111	5	0000 0111	30
0010 110	9	0000 0110	46
0010 101	17	0000 0101	54
0010 100	33	0000 0100	58
0010 011	6	0000 0011 1	31
0010 010	10	0000 0011 0	47
0010 001	18	0000 0010 1	55
0010 000	34	0000 0010 0	59
0001 1111	7	0000 0001 1	27
0001 1110	11	0000 0001 0	39
0001 1101	19	0000 0000 1	0 (Note)
NOTE – This entry shall not be used with 4:2:0 chrominance structure.			

B.4 Motion vectors

See Tables B.10 and B.11.

Table B.10 – Variable length codes for *motion_code*

Variable length code	***motion_code*[*r*][*s*][*t*]**
0000 0011 001	–16
0000 0011 011	–15
0000 0011 101	–14
0000 0011 111	–13
0000 0100 001	–12
0000 0100 011	–11
0000 0100 11	–10
0000 0101 01	–9
0000 0101 11	–8
0000 0111	–7
0000 1001	–6
0000 1011	–5
0000 111	–4
0001 1	–3
0011	–2
011	–1
1	0
010	1
0010	2
0001 0	3
0000 110	4
0000 1010	5
0000 1000	6
0000 0110	7
0000 0101 10	8
0000 0101 00	9
0000 0100 10	10
0000 0100 010	11
0000 0100 000	12
0000 0011 110	13
0000 0011 100	14
0000 0011 010	15
0000 0011 000	16

Table B.11 – Variable length codes for *dmvector*[*t*]

Code	Value
11	–1
0	0
10	1

B.5 DCT coefficients

See Tables B.12 to B.16.

Table B.12 – Variable length codes for dct_dc_size_luminance

Variable length code	**dct_dc_size_luminance**
100	0
00	1
01	2
101	3
110	4
1110	5
1111 0	6
1111 10	7
1111 110	8
1111 1110	9
1111 1111 0	10
1111 1111 1	11

Table B.13 – Variable length codes for dct_dc_size_chrominance

Variable length code	**dct_dc_size_chrominance**
00	0
01	1
10	2
110	3
1110	4
1111 0	5
1111 10	6
1111 110	7
1111 1110	8
1111 1111 0	9
1111 1111 10	10
1111 1111 11	11

Table B.14 – DCT coefficients Table zero

Variable length code (Note 1)	Run	Level
10 (Note 2)	End of Block	
1 s (Note 3)	0	1
11 s (Note 4)	0	1
011 s	1	1
0100 s	0	2
0101 s	2	1
0010 1 s	0	3
0011 1 s	3	1
0011 0 s	4	1
0001 10 s	1	2
0001 11 s	5	1
0001 01 s	6	1
0001 00 s	7	1
0000 110 s	0	4
0000 100 s	2	2
0000 111 s	8	1
0000 101 s	9	1
0000 01	Escape	
0010 0110 s	0	5
0010 0001 s	0	6
0010 0101 s	1	3
0010 0100 s	3	2
0010 0111 s	10	1
0010 0011 s	11	1
0010 0010 s	12	1
0010 0000 s	13	1
0000 0010 10 s	0	7
0000 0011 00 s	1	4
0000 0010 11 s	2	3
0000 0011 11 s	4	2
0000 0010 01 s	5	2
0000 0011 10 s	14	1
0000 0011 01 s	15	1
0000 0010 00 s	16	1

Table B.14 – DCT coefficients Table zero *(continued)*

Variable length code (Note 1)	Run	Level
0000 0001 1101 s	0	8
0000 0001 1000 s	0	9
0000 0001 0011 s	0	10
0000 0001 0000 s	0	11
0000 0001 1011 s	1	5
0000 0001 0100 s	2	4
0000 0001 1100 s	3	3
0000 0001 0010 s	4	3
0000 0001 1110 s	6	2
0000 0001 0101 s	7	2
0000 0001 0001 s	8	2
0000 0001 1111 s	17	1
0000 0001 1010 s	18	1
0000 0001 1001 s	19	1
0000 0001 0111 s	20	1
0000 0001 0110 s	21	1
0000 0000 1101 0 s	0	12
0000 0000 1100 1 s	0	13
0000 0000 1100 0 s	0	14
0000 0000 1011 1 s	0	15
0000 0000 1011 0 s	1	6
0000 0000 1010 1 s	1	7
0000 0000 1010 0 s	2	5
0000 0000 1001 1 s	3	4
0000 0000 1001 0 s	5	3
0000 0000 1000 1 s	9	2
0000 0000 1000 0 s	10	2
0000 0000 1111 1 s	22	1
0000 0000 1111 0 s	23	1
0000 0000 1110 1 s	24	1
0000 0000 1110 0 s	25	1
0000 0000 1101 1 s	26	1

Table B.14 – DCT coefficients Table zero *(continued)*

Variable length code (Note 1)	Run	Level
0000 0000 0111 11 s	0	16
0000 0000 0111 10 s	0	17
0000 0000 0111 01 s	0	18
0000 0000 0111 00 s	0	19
0000 0000 0110 11 s	0	20
0000 0000 0110 10 s	0	21
0000 0000 0110 01 s	0	22
0000 0000 0110 00 s	0	23
0000 0000 0101 11 s	0	24
0000 0000 0101 10 s	0	25
0000 0000 0101 01 s	0	26
0000 0000 0101 00 s	0	27
0000 0000 0100 11 s	0	28
0000 0000 0100 10 s	0	29
0000 0000 0100 01 s	0	30
0000 0000 0100 00 s	0	31
0000 0000 0011 000 s	0	32
0000 0000 0010 111 s	0	33
0000 0000 0010 110 s	0	34
0000 0000 0010 101 s	0	35
0000 0000 0010 100 s	0	36
0000 0000 0010 011 s	0	37
0000 0000 0010 010 s	0	38
0000 0000 0010 001 s	0	39
0000 0000 0010 000 s	0	40
0000 0000 0011 111 s	1	8
0000 0000 0011 110 s	1	9
0000 0000 0011 101 s	1	10
0000 0000 0011 100 s	1	11
0000 0000 0011 011 s	1	12
0000 0000 0011 010 s	1	13
0000 0000 0011 001 s	1	14

Table B.14 – DCT coefficients Table zero *(concluded)*

Variable length code (Note 1)	Run	Level
0000 0000 0001 0011 s	1	15
0000 0000 0001 0010 s	1	16
0000 0000 0001 0001 s	1	17
0000 0000 0001 0000 s	1	18
0000 0000 0001 0100 s	6	3
0000 0000 0001 1010 s	11	2
0000 0000 0001 1001 s	12	2
0000 0000 0001 1000 s	13	2
0000 0000 0001 0111 s	14	2
0000 0000 0001 0110 s	15	2
0000 0000 0001 0101 s	16	2
0000 0000 0001 1111 s	27	1
0000 0000 0001 1110 s	28	1
0000 0000 0001 1101 s	29	1
0000 0000 0001 1100 s	30	1
0000 0000 0001 1011 s	31	1

NOTE 1 – The last bit 's' denotes the sign of the level: '0' for positive, '1' for negative.
NOTE 2 – "End of Block" shall not be the only code of the block.
NOTE 3 – This code shall be used for the first (DC) coefficient in the block.
NOTE 4 – This code shall be used for all other coefficients.

Table B.15 – DCT coefficients Table one

Variable length code (Note 1)	Run	Level
0110 (Note 2)	End of Block	
10s	0	1
010 s	1	1
110 s	0	2
0010 1 s	2	1
0111 s	0	3
0011 1 s	3	1
0001 10 s	4	1
0011 0 s	1	2
0001 11 s	5	1
0000 110 s	6	1
0000 100 s	7	1
1110 0 s	0	4
0000 111 s	2	2
0000 101 s	8	1
1111 000 s	9	1
0000 01	Escape	
1110 1 s	0	5
0001 01 s	0	6
1111 001 s	1	3
0010 0110 s	3	2
1111 010 s	10	1
0010 0001 s	11	1
0010 0101 s	12	1
0010 0100 s	13	1
0001 00 s	0	7
0010 0111 s	1	4
1111 1100 s	2	3
1111 1101 s	4	2
0000 0010 0 s	5	2
0000 0010 1 s	14	1
0000 0011 1 s	15	1
0000 0011 01 s	16	1

Table B.15 – DCT coefficients Table one *(continued)*

Variable length code (Note 1)	Run	Level
1111 011 s	0	8
1111 100 s	0	9
0010 0011 s	0	10
0010 0010 s	0	11
0010 0000 s	1	5
0000 0011 00 s	2	4
0000 0001 1100 s	3	3
0000 0001 0010 s	4	3
0000 0001 1110 s	6	2
0000 0001 0101 s	7	2
0000 0001 0001 s	8	2
0000 0001 1111 s	17	1
0000 0001 1010 s	18	1
0000 0001 1001 s	19	1
0000 0001 0111 s	20	1
0000 0001 0110 s	21	1
1111 1010 s	0	12
1111 1011 s	0	13
1111 1110 s	0	14
1111 1111 s	0	15
0000 0000 1011 0 s	1	6
0000 0000 1010 1 s	1	7
0000 0000 1010 0 s	2	5
0000 0000 1001 1 s	3	4
0000 0000 1001 0 s	5	3
0000 0000 1000 1 s	9	2
0000 0000 1000 0 s	10	2
0000 0000 1111 1 s	22	1
0000 0000 1111 0 s	23	1
0000 0000 1110 1 s	24	1
0000 0000 1110 0 s	25	1
0000 0000 1101 1 s	26	1

Table B.15 – DCT coefficients Table one *(continued)*

Variable length code (Note 1)	Run	Level
0000 0000 0111 11 s	0	16
0000 0000 0111 10 s	0	17
0000 0000 0111 01 s	0	18
0000 0000 0111 00 s	0	19
0000 0000 0110 11 s	0	20
0000 0000 0110 10 s	0	21
0000 0000 0110 01 s	0	22
0000 0000 0110 00 s	0	23
0000 0000 0101 11 s	0	24
0000 0000 0101 10 s	0	25
0000 0000 0101 01 s	0	26
0000 0000 0101 00 s	0	27
0000 0000 0100 11 s	0	28
0000 0000 0100 10 s	0	29
0000 0000 0100 01 s	0	30
0000 0000 0100 00 s	0	31
0000 0000 0011 000 s	0	32
0000 0000 0010 111 s	0	33
0000 0000 0010 110 s	0	34
0000 0000 0010 101 s	0	35
0000 0000 0010 100 s	0	36
0000 0000 0010 011 s	0	37
0000 0000 0010 010 s	0	38
0000 0000 0010 001 s	0	39
0000 0000 0010 000 s	0	40
0000 0000 0011 111 s	1	8
0000 0000 0011 110 s	1	9
0000 0000 0011 101 s	1	10
0000 0000 0011 100 s	1	11
0000 0000 0011 011 s	1	12
0000 0000 0011 010 s	1	13
0000 0000 0011 001 s	1	14

Table B.15 – DCT coefficients Table one *(concluded)*

Variable length code (Note 1)	Run	Level
0000 0000 0001 0011 s	1	15
0000 0000 0001 0010 s	1	16
0000 0000 0001 0001 s	1	17
0000 0000 0001 0000 s	1	18
0000 0000 0001 0100 s	6	3
0000 0000 0001 1010 s	11	2
0000 0000 0001 1001 s	12	2
0000 0000 0001 1000 s	13	2
0000 0000 0001 0111 s	14	2
0000 0000 0001 0110 s	15	2
0000 0000 0001 0101 s	16	2
0000 0000 0001 1111 s	27	1
0000 0000 0001 1110 s	28	1
0000 0000 0001 1101 s	29	1
0000 0000 0001 1100 s	30	1
0000 0000 0001 1011 s	31	1
NOTE 1 –The last bit 's' denotes the sign of the level: '0' for positive, '1' for negative. NOTE 2 – "End of Block" shall not be the only code of the block.		

Table B.16 – Encoding of run and level following an ESCAPE code

Fixed length code	Run
0000 00	0
0000 01	1
0000 10	2
…	…
…	…
…	…
…	…
1111 11	63

Fixed length code	**signed_level**
1000 0000 0000	reserved
1000 0000 0001	–2047
1000 0000 0010	–2046
…	…
1111 1111 1111	–1
0000 0000 0000	Forbidden
0000 0000 0001	+1
…	…
0111 1111 1111	+2047

Annex C

Video buffering verifier

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

Coded video bitstreams shall meet constraints imposed through a Video Buffering Verifier (VBV) defined in this annex. Each bitstream in a scalable hierarchy shall not violate the VBV constraints defined in this annex.

The VBV is a hypothetical decoder, which is conceptually connected to the output of an encoder. It has an input buffer known as the VBV buffer. Coded data is placed in the buffer as defined below in C.3 and is removed from the buffer as defined in C.5, C.6, and C.7. It is required that a bitstream that conforms to this Specification shall not cause the VBV buffer to overflow. When low_delay equals zero, the bitstream shall not cause the VBV buffer to underflow. When low_delay equals one, decoding a picture at the normally expected time might cause the VBV buffer to underflow. If this is the case, the picture is not decoded and the VBV buffer is re-examined at a sequence of later times specified in C.7 and C.8 until it is all present in the VBV buffer.

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 the VBV buffer is not necessarily an integer.

C.1 The VBV and the video encoder have the same clock frequency as well as the same frame rate, and are operated synchronously.

C.2 The VBV buffer is of size B, where B is the vbv_buffer_size coded in the sequence header and sequence extension if present.

C.3 This subclause defines the input of data to the VBV buffer. Two mutually exclusive cases are defined in C.3.1 and C.3.2. In both cases the VBV buffer is initially empty. Let R_{max} be the bit rate specified in the bit_rate field.

C.3.1 In the case where vbv_delay is coded with a value not equal to hexadecimal FFFF, the picture data of the n-th coded picture enters the buffer at a rate R(n) where:

$$R(n) = d^*_n / (\tau(n) - \tau(n+1) + t(n+1) - t(n))$$

Where

- R(n) is the rate, in bits/s, that the picture data for the n-th coded picture enters the VBV.
- d^*_n is the number of bits after the final bit of the n-th picture start code and before and including the final bit of the (n + 1)-th picture start code.
- τ (n) is the decoding delay coded in vbv_delay for the n-th coded picture, measured in seconds.
- t(n) Is the time, measured in seconds, when the n-th coded picture is removed from VBV buffer. t(n) is defined in C.9, C.10, C.11, and C.12.

Ambiguity at the beginning of a sequence:

The interval of time $t_{n+1} - t_n$ between removal of two consecutive pictures can normally be derived from the bitstream as described in C.9, C.10, C.11 and C.12.

When random access is made in a sequence, $t_{n+1} - t_n$ cannot be determined from the video bitstream alone for the first picture(s) after the sequence header since the previous coded P- or I-frame does not exist in the decoded sequence. If the bitstream is multiplexed as part of a systems bitstream according to Rec. ITU-T H.222.0 | ISO/IEC 13818-1 [6], then it is possible (but not certain) that information in the systems bitstream may be used to determine unambiguously this interval of time. This information is available if Decoding Time Stamps (DTS) are transmitted for pictures n and n+1.

If the rate R(n) cannot be determined unambiguously, it is not possible for the VBV to precisely determine the fullness in trajectories in the VBV buffer during a limited period (always less than the maximum value for vbv_delay, which is approximately 0.73 seconds), therefore strict VBV verification of the entire bitstream is not always possible. Note that an encoder always knows the values of $t_{n+1} - t_n$ after each repeated sequence headers and therefore knows how to generate a bitstream that does not violate the VBV constraints at those points.

The ambiguity may become a problem when the video bitstream is remultiplexed and delivered at a rate different from the intended piecewise constant rate R(n).

It should also be noted that the input rate for the bits preceding the first picture header cannot be determined from the bitstream.

Ambiguity at the end of a sequence:

The input of all the bits following the picture start code of the picture preceding an end of sequence code cannot be determined from the bitstream. There shall exist an input rate for these bits that does not lead to an overflow or, if low_delay is equal to 1, an underflow of the VBV buffer. This rate shall be less than the maximum rate specified in the sequence header.

After filling the VBV buffer with all the data that precedes the first picture start code of the sequence and the picture start code itself, the VBV buffer is filled from the bitstream for the time specified by the vbv_delay field in the picture header. At this time decoding begins. The data input continues at the rates specified in this subclause.

For all bitstreams R(n) <= R_{max} for all picture data.

NOTE – For constant rate video the sequence of values R(n) are constant throughout the sequence to within the accuracy permitted by the quantization of vbv_delay.

C.3.2 In the case where vbv_delay is coded with the value hexadecimal FFFF, data enters the VBV buffer as specified in this subclause.

If the VBV buffer is not full, data enters the buffer at R_{max}.

If the VBV buffer becomes full after filling at R_{max} for some time, no more data enters the buffer until some data is removed from the buffer.

After filling the VBV buffer with all the data that precedes the first picture start code of the sequence and the picture start code itself, the VBV buffer is filled from the bitstream until it is full. At this time decoding begins. The data input continues at the rate specified in this subclause.

C.4 Starting at the time defined in C.3, the VBV buffer is examined at successive times defined in C.9 to C.12. C.5 to C.8 defines the actions to be taken at each time the VBV buffer is examined.

C.5 This subclause defines a requirement on all video bitstreams.

At the time the VBV buffer is examined *before* removing any picture data, the number of bits in the buffer shall lie between zero bits and B bits where B is the size of the VBV buffer indicated by vbv_buffer_size.

For the purpose of this annex, picture data is defined as all the bits of the coded picture, all the header(s) and user data immediately preceding it if any (including any stuffing between them) and all the stuffing following it, up to (but not including) the next start code, except in the case where the next start code is an end of sequence code, in which case it is included in the picture data.

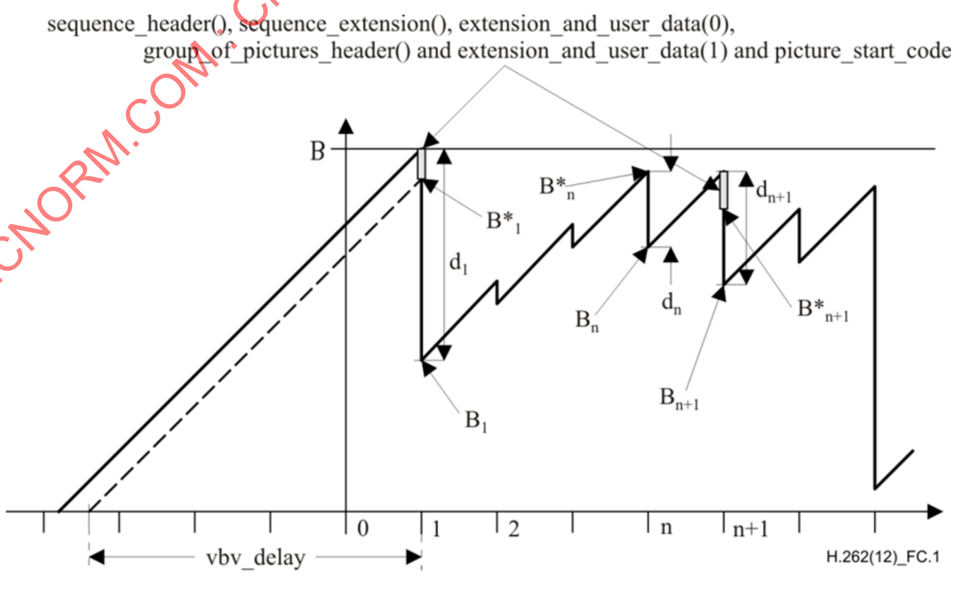


Figure C.1 – VBV buffer occupancy – Constant bit rate operation

C.6 This subclause defines a requirement on the video bitstreams when the low_delay flag is equal to zero.

At each time the VBV buffer is examined and before any bits are removed, all of the data for the picture which (at that time) has been in the buffer longest shall be present in the VBV buffer. This picture data shall be removed instantaneously at this time.

VBV buffer underflow shall not occur when the low_delay flag is equal to 0. This requires that all picture data for the n-th picture shall be present in the VBV buffer at the decoding time, t_n.

C.7 This subclause only applies when the low_delay flag is equal to one.

When low_delay is equal to one, there may be situations where the VBV buffer shall be re-examined several times before removing a coded picture from the VBV buffer. It is possible to know if the VBV buffer has to be re-examined and how many times by looking at the temporal_reference of the next picture (the one that follows the picture currently to be decoded), see 6.3.10. If the VBV buffer has to be re-examined, the picture currently to be decoded is referred to as a big picture.

If picture currently to be decoded is a big picture, the VBV buffer is re-examined at intervals of 2 field-periods before removing the big picture, and no picture data is removed until the final re-examination.

At this time, the number of bits the VBV buffer immediately before removing the big picture shall be less than B, all the picture data for the picture that has been in the buffer longest (the big picture) shall be present in the buffer and shall be removed instantaneously. Then, normal operation of the VBV resumes, and C.5 applies.

The last coded picture of a sequence shall not be a big picture.

C.8 This subclause is informative only.

The situation where the VBV buffer would underflow (see C.7) can happen when low-delay applications transmit occasionally large pictures, for example in case of scene-cuts.

Decoding such bitstreams will cause the display process associated with a decoder to repeat a previously decoded field or frame until normal operation of the VBV can resume. This process is sometimes referred to as the occurrence of "skipped pictures". Note that this situation should normally not occur except occasionally. It shall not occur when low_delay is equal to 0.

C.9 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 1 and low_delay equals to 0. In this case, the frame re-ordering delay always exists and B-pictures can occur.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV buffer is a multiple of T, where T is the inverse of the frame rate.

If the n-th picture is a B-picture with repeat_first_field equals to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a B-picture with repeat_first_field equal to 1 and top_field_first equals 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a B-picture with repeat_first_field equal to 1 and top_field_first equals 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a P-picture or I-picture and if the previous P-picture or I-picture has repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a P-picture or I-picture and if the previous P-picture or I-picture has repeat_first_field equal to 1 and top_field_first equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a P-picture or I-picture and if the previous P-picture or I-picture has repeat_first_field equal to 1 and top_field_first equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

C.10 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 1 and low_delay equals to 1. In this case the sequence contains no B-pictures and there is no frame re-ordering delay.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV buffer is a multiple of T, where T is the inverse of the frame rate.

If the n-th picture is a P-picture or I-picture with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a P-picture or I-picture with repeat_first_field equal to 1 and top_field_first equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a P-picture or I-picture with repeat_first_field equal to 1 and top_field_first equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

C.11 This subclause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 0 and low_delay equals to 0. In this case, the frame re-ordering delay always exists and B-pictures can occur.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV input buffer is a multiple of T, where T is the inverse of two times the frame rate.

If the n-th picture is a *frame-structure* coded B-frame with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded B-frame with repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a *field-structure* B-picture (B-field picture), then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is a *frame-structure* coded P-frame or coded I-frame and if the previous coded P-frame or coded I-frame has repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded P-frame or coded I-frame and if the previous coded P-frame or coded I-frame has repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is the *first* field of a *field-structure* coded P-frame or coded I-frame, then $t_{n+1} - t_n$ is equal to T.

If the n-th picture is the *second* field of a *field-structure* coded P-frame or coded I-frame and if the previous coded P-frame or coded I-frame is using field-structure or has *repeat_first_field* equal to 0, then $t_{n+1} - t_n$ is equal to (2*T – T).

If the n-th picture is the *second* field of a *field-structure* coded P-frame or coded I-frame and if the previous coded P-frame or coded I-frame is using frame-structure and has *repeat_first_field* equal to 1, then $t_{n+1} - t_n$ is equal to (3*T – T).

Figure C.2 shows the VBV in a simple case with only frame pictures. Frames P_0, B_2 and B_4 have a display duration of 3 fields.

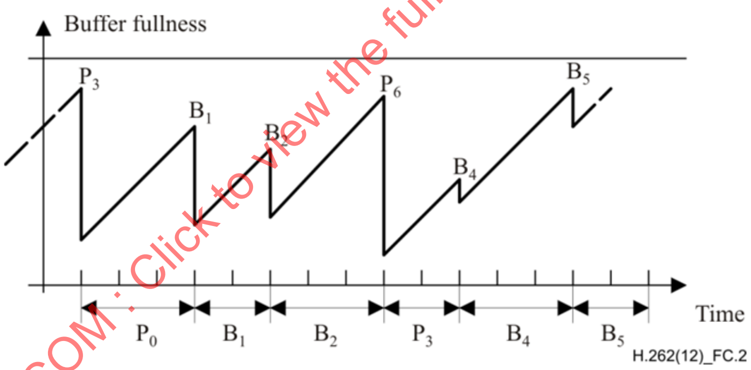


Figure C.2 – Example VBV with B-pictures

C.12 This clause defines the time intervals between successive examination of the VBV buffer in the case where progressive_sequence equals to 0 and low_delay equals to 1. In this case the sequence contains no B-pictures and there is no frame re-ordering delay.

The time interval $t_{n+1} - t_n$ between two successive examinations of the VBV input buffer is a multiple of T, where T is the inverse of two times the frame rate.

If the n-th picture is a *frame-structure* coded P-frame or coded I-frame with repeat_first_field equal to 0, then $t_{n+1} - t_n$ is equal to 2*T.

If the n-th picture is a *frame-structure* coded P-frame or coded I-frame with repeat_first_field equal to 1, then $t_{n+1} - t_n$ is equal to 3*T.

If the n-th picture is a *field-structure* coded P-frame or coded I-frame, then $t_{n+1} - t_n$ is equal to T.

Figure C.3 shows the VBV in a simple case with only frame pictures. Frames I_0, P_2 and P_4 have repeat_first_field equal to 1.

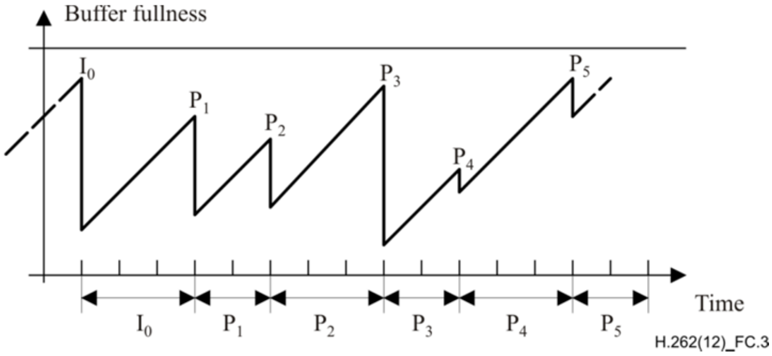


Figure C.3 – Example VBV without B-pictures

Annex D

Frame packing arrangement signalling for stereoscopic 3D content

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

The annex specifies a method to carry frame packing arrangement information used for such applications as stereoscopic video indication in bitstreams encoded according to this Specification.

The frame packing arrangement signalling information is inserted in the picture layer user data of video bitstreams encoded according to this Specification. The signalling specified in this annex supports switching between 2D and stereoscopic 3D video at frame boundaries, as well as between different frame packing arrangements for stereoscopic 3D video at frame boundaries.

For compatibility with existing video decoders, the method uses an indicator to be provided in extensions_and_user_data(2), which follows the picture_header() and picture_coding_extension().

The following syntax and semantics are specified for indicating a frame packing arrangement in the user_data bytes of the user_data() syntax structure of extensions_and_user_data(2). The syntax structure sent in these user_data bytes for this purpose is specified as follows.

frame_packing_arrangement_data() {	No. of bits	Mnemonic
frame_packing_user_data_identifier	32	bslbf
remaining_data_length	8	uimsbf
reserved_bit	1	uimsbf
arrangement_type	7	bslbf
reserved_data	16	bslbf
for (i = 3; i < remaining_data_length; i ++)		
additional_reserved_data_byte	8	bslbf
}		

frame_packing_user_data_identifier – The bit string '4a503344' in hexadecimal. When the user_data bytes of the user_data() syntax structure begin with this bit string, the remaining bytes of the user_data() syntax structure shall conform to the frame_packing_arrangement_data() syntax structure.

NOTE 1 – This frame packing user data identifier is a 4-byte code value that has been selected to avoid conflict with other applications of the user_data() mechanism.

remaining_data_length – Shall be set to 3. Other values are reserved for possible future extensions defined by ITU-T | ISO/IEC. Decoders shall use the value of this syntax element to determine the quantity of additional_reserved_data_byte syntax elements as specified in the frame_packing_arrangement_data() syntax diagram.

reserved_bit – Shall be set to the value '1'. The value '0' is reserved for possible future extensions defined by ITU-T | ISO/IEC. Decoders shall ignore (i.e. remove from the bitstream and discard) the value of this bit.

arrangement_type – See Table D.1.

Table D.1 – Semantics of arrangement_type

arrangement_type	Meaning
0000011	stereo side-by-side (with rectangular grid sampling)
0000100	stereo top-and-bottom (with rectangular grid sampling)
0001000	2D video (with rectangular grid sampling)
0100011	stereo side-by-side with quincunx sampling
other values	reserved for possible future extensions defined by ITU-T | ISO/IEC

reserved_data – This is a 16-bit integer that shall be set to the bit string '04FF' in hexadecimal. All other values are reserved for possible future extensions defined by ITU-T | ISO/IEC. Decoders shall ignore (i.e. remove from the bitstream and discard) the value of these 16 bits.

additional_reserved_data_byte – The use of this syntax element is reserved for possible future extensions defined by ITU-T | ISO/IEC.

It is recommended that for the entire duration of a bitstream containing stereo 3D video content, the video bitstream should contain user data with frame_packing_arrangement_data() for every picture.

In the case of the "stereo side-by-side" arrangement indication, the picture is divided into two halves, each of which has half resolution horizontally (relative to the displayable part of the encoded picture). The left view is on the left side of the displayable part of the encoded picture, and the right view is on the right side of the displayable part of the encoded picture. The border position between the two halves is at the centre of the displayable part of each scan line within the displayable part of the encoded picture. The indicated sampling positions, relative to the sampling grid of a hypothetical upconverted full-resolution picture, are the same for the samples in both halves. The sampling positions for the "stereo side-by-side" arrangement are shown in Figure D.1.

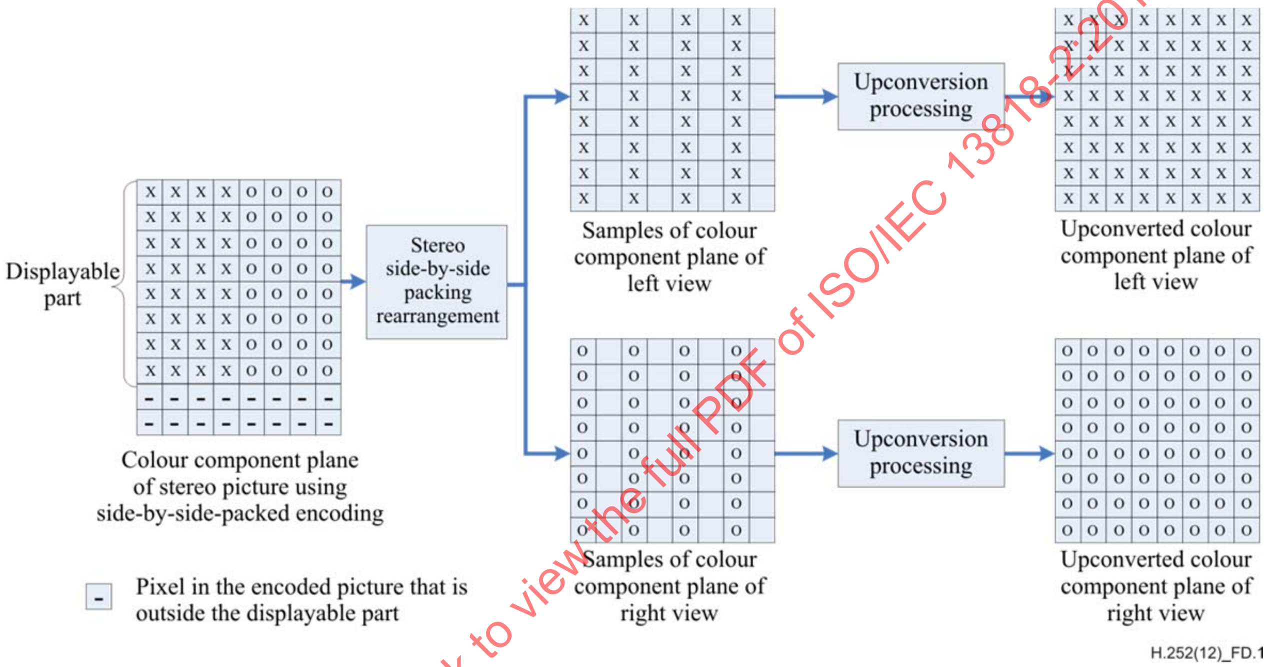


Figure D.1 – Rearrangement and hypothetical upconversion of "stereo side-by-side" arrangement views to convert to the full resolution of the displayable part of the encoded picture

NOTE 2 – Pixels marked as "-" in Figure D.1 illustrate pixels in the encoded picture that are outside the displayable part. These pixels are discarded after the decoding of the picture.

In the case of the "stereo top-and-bottom" arrangement indication, the picture is divided into two halves, each of which has half resolution vertically (relative to the displayable part of the encoded picture). The left view is in the upper part of the displayable part of the encoded picture, and the right view is in the lower part of the displayable part of the encoded picture. The border position between the two halves is at the centre of the displayable part of each column within the displayable part of the encoded picture. The indicated sampling positions, relative to the sampling grid of a hypothetical upconverted full-resolution picture, are the same for the samples in both halves. The sampling positions for the "stereo top-and-bottom" arrangement are shown in Figure D.2.

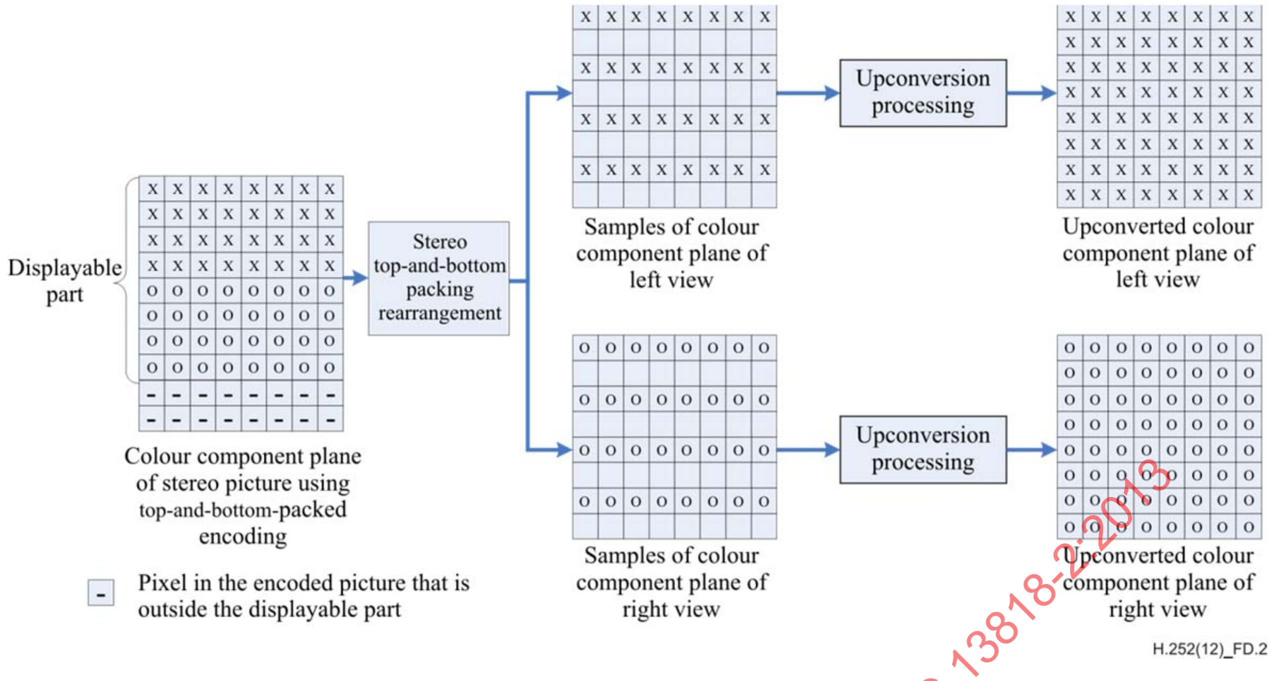


Figure D.2 – Rearrangement and hypothetical upconversion of "stereo top-and-bottom" arrangement views to convert to the full resolution of the displayable part of the encoded picture

NOTE 3 – Pixels marked as "-"in Figure D.2 illustrate pixels in the encoded picture that are outside the displayable part of the encoded picture. These pixels are discarded after the decoding of the picture.

In the case of the "2D video" arrangement indication, the picture contains only the pixels for a single 2D view of the scene content, and this view covers the entire displayable part of the encoded picture.

When 2D and 3D content may be present in the same elementary stream, the arrangement_type should be used to indicate the arrangement type for each picture. When the frame packing arrangement is changed within a video bitstream, the arrangement_type indication should change in the same picture in which the content change occurs.

In the case of the "stereo side-by-side-with-quincunx-sampling" arrangement indication, the picture is divided into two halves, each of which has half resolution representing a quincunx pattern sampling (relative to the displayable part of the encoded picture). The left view is on the left side of the displayable part of the encoded picture and the right view is on the right side of the displayable part of the encoded picture. The border position between the two halves is at the centre of the displayable part of each scan line within the displayable part of the encoded picture. The indicated sampling positions, relative to the sampling grid of a hypothetical upconverted full-resolution picture, are different for the samples in each half. The sampling positions for the "stereo side-by-side-with-quincunx-sampling" arrangement are shown in Figure D.3.

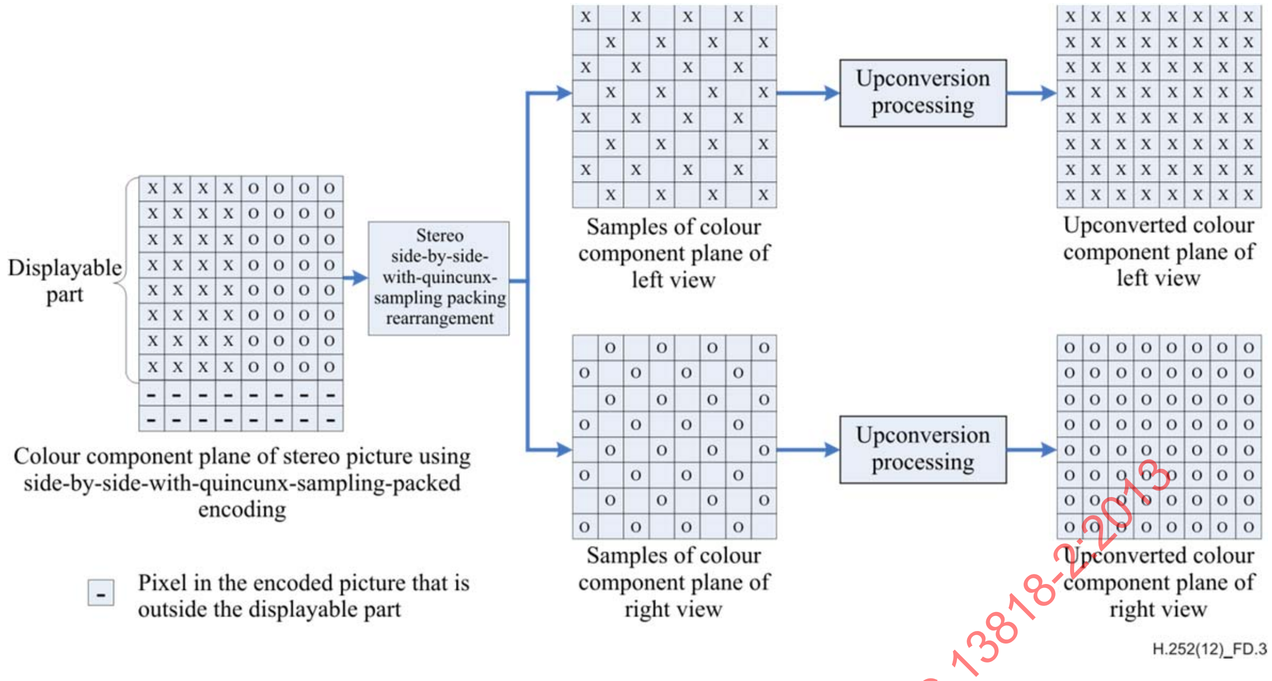


Figure D.3 – Rearrangement and hypothetical upconversion of "stereo side-by-side with quincunx sampling" arrangement views to convert to the full resolution of the displayable part of the encoded picture

NOTE 4 – Pixels marked as "-" in Figure D.3 illustrate pixels in the encoded picture that are outside the displayable part. These pixels are discarded after the decoding of the picture.

Annex E

Profile and level restrictions

(This annex does not form an integral part of this Recommendation | International Standard.)

E.1 Syntax element restrictions in profiles

This annex tabulates all of the syntactic elements defined in this Specification. Each is classified to indicate whether it is required to be supported by a decoder compliant to a particular profile and level. Note that normative specifications for compliance are given in ISO/IEC 13818-4 [15].

NOTE – This annex is informative and is simply intended as a summary of the normative restrictions set out in clause 8. If, because of an error in the preparation of this text, a discrepancy exists between clause 8 and Annex E, the normative text in clause 8 shall always take precedence.

In Tables E.2 to E.20 a number of abbreviations are used as shown in Table E.1.

Table E.1 – Abbreviations used in the Tables of Annex E

Abbreviation	Used in	Meaning
x	Status	Must be supported by the decoder.
o	Status	Need not be supported by the decoder.
D	Type	Item with Level-dependent parameters.
I	Type	Item independent of the Level in the Profile.
P	Type	Item for post-processing after decoding; the decoder must be capable of decoding bitstreams which contain these items, but their use is beyond the scope of this Recommendation | International Standard.
NOTE – "Status" is kept blank if an entry is not a syntactic element.		

Table E.2 – Sequence header

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
		Status							Type	
01	**horizontal_size_value**	x	x	x	x	x	x	x	D	Table 8-11
02	**vertical_size_value**	x	x	x	x	x	x	x	D	Table 8-11
03	**aspect_ratio_information**	x	x	x	x	x	x	x	P	
04	**frame_rate_code**	x	x	x	x	x	x	x	D	Table 8-11
05	(sample rate) NOTE – This is not a syntactic element								D	Table 8-12. Sample rate is a product of samples/line, lines/frame and frames/sec.
06	**bit_rate_value**	x	x	x	x	x	x	x	D	Table 8-13
07	**vbv_buffer_size_value**	x	x	x	x	x	x	x	D	Table 8-14
08	**constrained_parameters_flag**	x	x	x	x	x	x	x	I	Set to "1" if ISO/IEC 11172-2 constrained, Set to "0" if Rec. ITU-T H.262 | ISO/IEC 13818-2
09	**load_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
10	**intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
11	**load_non_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
12	**non_intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
13	sequence_extension()	x	x	x	x	x	x	x	I	Always present if Rec. ITU-T H.262 | ISO/IEC 13818-2
14	sequence_display_extension()	x	x	x	x	x	x	x	P	
15	sequence_scalable_extension()	o	o	x	x	x	o	x	I	Table 8-9 for maximum number of scalable layers
16	user_data()	x	x	x	x	x	x	x	I	Decoder may skip this data

Table E.3 – Sequence extension

#	Syntactic elements	Status: SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**profile_and_level_indication**	x	x	x	x	x	x	x	D	Profile: one of 8 values Level: one of 16 values Escape bit: one of 2 values
02	**progressive_sequence**	x	x	x	x	x	x	x	I	
03	**chroma_format**	x	x	x	x	x	x	x	I	Table 8-5
04	**horizontal_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
05	**vertical_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
06	**bit_rate_extension**	x	x	x	x	x	x	x	D	Input picture size related
07	**vbv_buffer_size_extension**	x	x	x	x	x	x	x	D	Input picture size related
08	**low_delay**	x	x	x	x	x	x	x	I	
09	**frame_rate_extension_n**	x	x	x	x	x	x	x	I	Set to "0" for all defined profiles
10	**frame_rate_extension_d**	x	x	x	x	x	x	x	I	Set to "0" for all defined profiles

Table E.4 – Sequence display extension elements

#	Syntactic elements	Status: SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**video_format**	x	x	x	x	x	x	x	P	
02	**colour_description**	x	x	x	x	x	x	x	P	Input format related
03	**colour_primaries**	x	x	x	x	x	x	x	P	
04	**transfer_characteristics**	x	x	x	x	x	x	x	P	
05	**matrix_coefficients**	x	x	x	x	x	x	x	P	
06	**display_horizontal_size**	x	x	x	x	x	x	x	P	Input format related
07	**display_vertical_size**	x	x	x	x	x	x	x	P	Input format related

Table E.5 – Sequence scalable extension

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**scalable_mode**	o	o	x	x	x	o	x	I	SNR Profile: SNR Scalability Spatial and High Profile: SNR and/or Spatial Scalability Multi-view Profile: Temporal Scalability
02	**layer_id**	o	o	x	x	x	o	x	I	
	if (spatial scalable)									
03	**lower_layer_prediction_ horizontal_size**	o	o	o	x	x	o	o	D	Table 8-12 for luminance sampling density
04	**lower_layer_prediction_ vertical_size**	o	o	o	x	x	o	o	D	Table 8-12 for luminance sampling density
05	**horizontal_subsampling_ factor_m**	o	o	o	x	x	o	o	I	
06	**horizontal_subsampling_ factor_n**	o	o	o	x	x	o	o	I	
07	**vertical_subsampling_ factor_m**	o	o	o	x	x	o	o	I	
08	**vertical_subsampling_ factor_n**	o	o	o	x	x	o	o	I	
	if (temporal scalable)									
09	**picture_mux_enable**	o	o	o	o	o	o	x	I	
10	**mux_to_progressive_sequence**	o	o	o	o	o	o	x	I	
11	**picture_mux_order**	o	o	o	o	o	o	x	I	
12	**picture_mux_factor**	o	o	o	o	o	o	x	I	

Table E.6 – Group of pictures header

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**time_code**	x	x	x	x	x	x	x	I	Decoder may skip this data
02	**closed_gop**	x	x	x	x	x	x	x	I	
03	**broken_link**	x	x	x	x	x	x	x	I	

Table E.7 – Picture header

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**temporal_reference**	x	x	x	x	x	x	x	I	
02	**picture_coding_type**	x	x	x	x	x	x	x	I	Simple Profile: I, P at Main level, I, P, B at Low level Main, SNR, Spatial, High and Multi-view Profile: I, P, B
03	**vbv_delay**	x	x	x	x	x	x	x	I	
04	**full_pel_forward_vector**	x	x	x	x	x	x	x	I	Set to "0" for Rec. ITU-T H.262 | ISO/IEC 13818-2
05	**forward_f_code**	x	x	x	x	x	x	x	I	Set to "111" for Rec. ITU-T H.262 | ISO/IEC 13818-2
06	**full_pel_backward_vector**	x	x	x	x	x	x	x	I	Set to "0" for Rec. ITU-T H.262 | ISO/IEC 13818-2
07	**backward_f_code**	x	x	x	x	x	x	x	I	Set to "111" for Rec. ITU-T H.262 | ISO/IEC 13818-2
08	content_description_data()	x	x	x	x	x	x	x	I	
09	picture_coding_extension()	x	x	x	x	x	x	x	I	
10	quant_matrix_extension()	x	x	x	x	x	x	x	I	
11	picture_display_extension()	x	x	x	x	x	x	x	P	
12	picture_spatial_scalable_extension()	o	o	o	x	x	o	o	I	
13	picture_temporal_scalable_extension()	o	o	o	o	o	o	x	I	
14	camera_parameters_extension()	o	o	o	o	o	o	x	P	

Table E.8 – Picture coding extension

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**f_code[0][0] (forward horizontal)**	x	x	x	x	x	x	x	D	Low Level [1:7] Main Level [1:8] High-1440 and High Level [1:9]
02	**f_code[0][1] (forward vertical)**	x	x	x	x	x	x	x	D	Low Level [1:4] Main, High-1440 and High Level [1:5]
03	**f_code[1][0](backward horizontal)**	x	x	x	x	x	x	x	D	Low Level [1:7] Main Level [1:8] High-1440 and High Level [1:9]
04	**f_code[1][1] (backward vertical)**	x	x	x	x	x	x	x	D	Low level [1:4] Main, H-14 and High Level [1:5]
05	**intra_dc_precision**	x	x	x	x	x	x	x	I	Simple, Main, SNR, Spatial and Multi-view Profile: [8:10] High Profile: [8:11] 4:2:2 Profile: [8:11]
06	**picture_structure**	x	x	x	x	x	x	x	I	
07	**top_field_first**	x	x	x	x	x	x	x	I	
08	**frame_pred_frame_dct**	x	x	x	x	x	x	x	I	
09	**concealment_motion_vectors**	x	x	x	x	x	x	x	I	
10	**q_scale_type**	x	x	x	x	x	x	x	I	
11	**intra_vlc_format**	x	x	x	x	x	x	x	I	
12	**alternate_scan**	x	x	x	x	x	x	x	I	
13	**repeat_first_field**	x	x	x	x	x	x	x	I	
14	**chroma_420_type**	x	x	x	x	x	x	x	P	
15	**progressive_frame**	x	x	x	x	x	x	x	P	
16	**composite_display_flag**	x	x	x	x	x	x	x	P	
17	**v_axis**	x	x	x	x	x	x	x	P	
18	**field_sequence**	x	x	x	x	x	x	x	P	
19	**sub_carrier**	x	x	x	x	x	x	x	P	
20	**burst_amplitude**	x	x	x	x	x	x	x	P	
21	**sub_carrier_phase**	x	x	x	x	x	x	x	P	

Table E.9 – Quant matrix extension

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**load_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
02	**intra_quantiser_matrix[64]**	x	x	x	x	x	x	x	I	
03	**load_non_intra_quantiser_matrix**	x	x	x	x	x	x	x	I	
04	**non_intra_quantiser_ matrix[64]**	x	x	x	x	x	x	x	I	
05	**load_chroma_intra_quantiser_ matrix**	o	o	o	o	x	x	o	I	
06	**chroma_intra_quantiser_ matrix[64]**	o	o	o	o	x	x	o	I	
07	**load_chroma_non_intra_ quantiser_matrix**	o	o	o	o	x	x	o	I	
08	**chroma_non_intra_quantiser_ matrix[64]**	o	o	o	o	x	x	o	I	

Table E.10 – Picture display extension

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**frame_centre_horizontal_offset**	x	x	x	x	x	x	x	P	Input format related
02	**frame_centre_vertical_offset**	x	x	x	x	x	x	x	P	Input format related

Table E.11 – Picture temporal scalable extension

#	Status								Type	
	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		Comments
01	**reference_select_code**	o	o	o	o	o	o	x	I	
02	**forward_temporal_reference**	o	o	o	o	o	o	x	I	
03	**backward_temporal_reference**	o	o	o	o	o	o	x	I	

Table E.12 – Picture spatial scalable extension

#	Status								Type	
	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view		Comments
01	**lower_layer_temporal_reference**	o	o	o	x	x	o	o	I	
02	**lower_layer_horizontal_offset**	o	o	o	x	x	o	o	D	Input format related
03	**lower_layer_vertical_offset**	o	o	o	x	x	o	o	D	Input format related
04	**spatial_temporal_weight_code_ table_index**	o	o	o	x	x	o	o	I	
05	**lower_layer_progressive_frame**	o	o	o	x	x	o	o	I	
06	**lower_layer_deinterlaced_field_ select**	o	o	o	x	x	o	o	I	

Table E.13 – Camera parameters extension

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**reserved**	o	o	o	o	o	o	x	P	
02	**camera_id**	o	o	o	o	o	o	x	P	
03	**marker_bit**	o	o	o	o	o	o	x	P	
04	**height_of_image_device**	o	o	o	o	o	o	x	P	
05	**marker_bit**	o	o	o	o	o	o	x	P	
06	**focal_length**	o	o	o	o	o	o	x	P	
07	**marker_bit**	o	o	o	o	o	o	x	P	
08	**f_number**	o	o	o	o	o	o	x	P	
09	**marker_bit**	o	o	o	o	o	o	x	P	
10	**vertical_angle_of_view**	o	o	o	o	o	o	x	P	
11	**marker_bit**	o	o	o	o	o	o	x	P	
12	**camera_position_x_upper**	o	o	o	o	o	o	x	P	
13	**marker_bit**	o	o	o	o	o	o	x	P	
14	**camera_position_x_lower**	o	o	o	o	o	o	x	P	
15	**marker_bit**	o	o	o	o	o	o	x	P	
16	**camera_position_y_upper**	o	o	o	o	o	o	x	P	
17	**marker_bit**	o	o	o	o	o	o	x	P	
18	**camera_position_y_lower**	o	o	o	o	o	o	x	P	
19	**marker_bit**	o	o	o	o	o	o	x	P	
20	**camera_position_z_upper**	o	o	o	o	o	o	x	P	
21	**marker_bit**	o	o	o	o	o	o	x	P	
22	**camera_position_z_lower**	o	o	o	o	o	o	x	P	
23	**marker_bit**	o	o	o	o	o	o	x	P	
24	**camera_direction_x**	o	o	o	o	o	o	x	P	
25	**marker_bit**	o	o	o	o	o	o	x	P	
26	**camera_direction_y**	o	o	o	o	o	o	x	P	
27	**marker_bit**	o	o	o	o	o	o	x	P	
28	**camera_direction_z**	o	o	o	o	o	o	x	P	
29	**marker_bit**	o	o	o	o	o	o	x	P	
30	**image_plane_vertical_x**	o	o	o	o	o	o	x	P	
31	**marker_bit**	o	o	o	o	o	o	x	P	
32	**image_plane_vertical_y**	o	o	o	o	o	o	x	P	
33	**marker_bit**	o	o	o	o	o	o	x	P	
34	**image_plane_vertical_z**	o	o	o	o	o	o	x	P	
35	**reserved**	o	o	o	o	o	o	x	P	

Table E.14 – Slice layer

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
		Status							Type	
01	**slice_vertical_position_extension**	x	x	x	x	x	x	x	D	Input format related
02	**priority_breakpoint**	o	o	o	o	o	o	o	I	Only required for data partitioning
03	**quantiser_scale_code**	x	x	x	x	x	x	x	I	
04	**slice_extension_flag**	x	x	x	x	x	x	x	I	
05	**intra_slice**	x	x	x	x	x	x	x	I	Decoder may skip this data
06	**slice_picture_id_enable**	x	x	x	x	x	x	x	I	Decoder may skip this data
07	**slice_picture_id**	x	x	x	x	x	x	x	I	Decoder may skip this data
08	**extra_bit_slice**	x	x	x	x	x	x	x	I	Decoder may skip this data
09	macroblock()	x	x	x	x	x	x	x	I	

Table E.15 – Macroblock layer

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
		Status							Type	
01	**macroblock_escape**	x	x	x	x	x	x	x	I	
02	**macroblock_address_increment**	x	x	x	x	x	x	x	I	
03	macroblock_modes()	x	x	x	x	x	x	x	I	
04	**quantiser_scale_code**	x	x	x	x	x	x	x	I	
05	motion_vectors(0)	x	x	x	x	x	x	x	I	Forward motion vector
06	motion_vectors(1)	o	x	x	x	x	x	x	I	Backward motion vector
07	coded_block_pattern()	x	x	x	x	x	x	x	I	
08	block(i)	x	x	x	x	x	x	x	I	

Table E.16 – Macroblock modes

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
	Status									
01	**macroblock_type**	x	x	x	x	x	x	x	I	
02	**spatial_temporal_weight_code**	o	o	o	x	x	o	o	I	
03	**frame_motion_type**	x	x	x	x	x	x	x	I	01: Field-based prediction 10: Frame-based prediction 11: Dual-prime
04	**field_motion_type**	x	x	x	x	x	x	x	I	01: Field-based prediction 10: 16 × 8 MC 11: Dual-prime
05	**dct_type**	x	x	x	x	x	x	x	I	

Table E.17 – Motion vectors

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
	Status									
01	**motion_vertical_field_select**	x	x	x	x	x	x	x	I	
02	motion_vector()	x	x	x	x	x	x	x	I	

Table E.18 – Motion vector

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**motion_horizontal_code**	x	x	x	x	x	x	x	I	
02	**motion_horizontal_r**	x	x	x	x	x	x	x	I	
03	**dmv_horizontal**	x	x	x	x	x	x	x	I	
04	**motion_vertical_code**	x	x	x	x	x	x	x	I	
05	**motion_vertical_r**	x	x	x	x	x	x	x	I	
06	**dmv_vertical**	x	x	x	x	x	x	x	I	

Table E.19 – Coded block pattern

#	Syntactic elements	SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	**coded_block_pattern_420**	x	x	x	x	x	x	x	I	
02	**coded_block_pattern_1**	o	o	o	o	x	x	o	I	4:2:2
03	**coded_block_pattern_2**	o	o	o	o	o	o	o	I	4:4:4

Table E.20 – Block layer

#	Syntactic elements	Status: SIMPLE	MAIN	SNR	SPATIAL	HIGH	4:2:2	Multi-view	Type	Comments
01	DCT coefficients	x	x	x	x	x	x	x	I	
02	End of block	x	x	x	x	x	x	x	I	

E.2 Permissible layer combinations

Tables E.21 to E.52 illustrate the parameter limits that may be applied in each layer of a bitstream, and the corresponding appropriate profile_and_level_indication that should be used. Each table describes the limits of a single compliance point in the profile / level matrix.

The following notation has been adopted:

<profile abbreviation>@<level abbreviation>

The abbreviations are defined in Table E.21.

Table E.21 – Abbreviations for profile and level names

Profile	<profile abbreviation>	Level	<level abbreviation>
Simple	SP	Low	LL
Main	MP	Main	ML
SNR Scalable	SNR	High-1440	H-14
Spatially Scalable	Spt	High	HL
High	HP	HighP	HPL
Multi-view	MVP		
ISO/IEC 11172-2 constrained parameters			ISO/IEC 11172-2

Table E.22 – Simple profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML

Table E.23 – Main profile @ Low level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	352/288/30	3 041 280	4	475 136	MP@LL

Table E.24 – Main profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML

Table E.25 – Main profile @ High-1440 level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	1440/1088/60	47 001 600	60	7 340 032	MP@H-14

Table E.26 – Main profile @ High level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	1920/1088/60	62 668 800	80	9 781 248	MP@HL

Table E.27 – Main profile @ HighP level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	1920/1088/60	125 337 600	80	9 781 248	MP@HPL

Table E.28 – SNR profile @ Low level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	4	475 136	SNR@LL
2	0	Base	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
2	0	Base	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL

Table E.29 – SNR profile @ Main level

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	720/576/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	720/576/30	2 534 400	15	1 835 008	SNR@ML
2	0	Base	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	15	1 835 008	SNR@ML
2	0	Base	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML

Table E.30 – Spatial profile @ High-1440 level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	720/576/30	10 368 000	60	7 340 032	Spt@H-14
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	720/576/30	10 368 000	60	7 340 032	Spt@H-14
2	0	Base	1440/1088/60	47 001 600	40	4 882 432	MP@H-14
	1	SNR	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.31 – Spatial profile @ High-1440 level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	768/576/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
2	0	Base	1440/1088/60	47 001 600	40	4 882 432	MP@H-14
	1	Spatial	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.32 – Spatial profile @ High-1440 level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	352/288/30	2 534 400	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	2 534 400	1.856	327 680	ISO 11172
	1	SNR	720/576/30	2 534 400	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	352/288/30	3 041 280	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	1440/1088/60	10 368 000	15	1 835 008	MP@H-14
	1	SNR	1440/1088/60	10 368 000	40	4 882 432	Spt@H-14
	2	Spatial	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14

Table E.33 – Spatial profile @ High-1440 level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	768/576/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	1440/1088/30	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14
3	0	Base	720/576/30	10 368 000	15	1 835 008	MP@H-14
	1	Spatial	1440/1088/60	47 001 600	40	4 882 432	Spt@H-14
	2	SNR	1440/1088/30	47 001 600	60	7 340 032	Spt@H-14

Table E.34 – High profile @ Main level (Base Layer)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
1	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.35 – High profile @ Main level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:2	352/288/30	3 041 280	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
2	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.36 – High profile @ Main level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.37 – High profile @ Main level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.38 – High profile @ Main level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	SP@ML
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	2	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	2	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML

Table E.39 – High profile @ High-1440 level (Base Layer)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
1	0	Base	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
1	0	Base	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.40 – High profile @ High-1440 level (Base Layer + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	SNR	4:2:2	352/288/30	3 041 280	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	MP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	14 745 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	720/576/30	11 059 200	20	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	1	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	1	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.41 – High profile @ High-1440 level (Base Layer + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	MP@H-14
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	MP@H-14
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
2	0	Base	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
2	0	Base	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.42 – High profile @ High-1440 level (Base Layer + SNR + Spatial)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	SP@ML
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	SP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	3	360 448	MP@LL
	1	SNR	4:2:0	352/288/30	3 041 280	4	475 136	SNR@LL
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	10	1 212 416	MP@ML
	1	SNR	4:2:0	720/576/30	10 368 000	15	1 835 008	SNR@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	SNR	4:2:2	720/576/30	10 368 000	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	14 745 600	15	1 835 008	HP@ML
	1	SNR	4:2:0	720/576/30	14 745 600	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:2	720/576/30	11 059 200	15	1 835 008	HP@ML
	1	SNR	4:2:2	720/576/30	11 059 200	20	2 441 216	HP@ML
	2	Spatial	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14

Table E.43 – High profile @ High-1440 level (Base Layer + Spatial + SNR)

No. of layers	layer id	Scalable mode	Chroma Format	Maximum sample density (H/V/F)	Maximum sample rate	Maximum total bit rate /1000000	Maximum total VBV buffer	Profile and level indication
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	2 534 400	1.856	327 680	ISO 11172
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	SP@ML
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:0	1440/1088/60	62 668 800	60	7 340 032	HP@H-14
	2	SNR	4:2:0	1440/1088/60	62 668 800	80	9 781 248	HP@H-14
3	0	Base	4:2:0	352/288/30	3 041 280	4	475 136	MP@LL
	1	Spatial	4:2:2	1440/1088/60	47 001 600	60	7 340 032	HP@H-14
	2	SNR	4:2:2	1440/1088/60	47 001 600	80	9 781 248	HP@H-14
3	0	Base	4:2:0	720/576/30	10 368 000	15	1 835 008	MP@ML
	1	Spatial	4:2:0	1440/1088/60	47 001 600	60	7 340 032	Spt@H-14
	2	SNR	4:2:0	1440/1088/60	47 001 600	80	9 781 248	HP@H-14