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Part 1:
Essential video coding

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This document was prepared by Joint Technical Committee ISO/IEC JTC 1, Subcommittee SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

A list of all parts in the ISO/IEC 23094 series can be found on the ISO website.

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Information technology – General Video Coding – Part 1: Essential Video Coding

1 Scope

This International Standard specifies essential video coding.

2 Normative references

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

2.1 International Standards

– None

2.2 Additional references

– ISO/IEC 10646: in force, *Information technology – Universal Coded Character Set (UCS)*.

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

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3 Definitions

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

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

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

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

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

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

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

3.7 **byte stream**: An encapsulation of a *NAL unit stream* containing *NAL unit length field* and *NAL units* as specified in Annex B.

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

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

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

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

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

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

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

3.14 **coding block**: An MxN *block* of samples for some values of M and N such that the division of a *CTB* into *coding blocks* is a *partitioning*.

3.15 **coding tree block (CTB)**: An NxN *block* of samples for some value of N such that the division of a *component* into *CTBs* is a *partitioning*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.32 **instantaneous decoding refresh (IDR) picture**: A *coded picture* for which each *VCL NAL unit* has NalUnitType equal to IDR_NUT.

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

3.34 **inter prediction**: A *prediction* derived in a manner that is dependent on data elements (e.g., sample values or motion vectors) of one or more *reference pictures*.

NOTE – A prediction from a reference picture that is the current picture itself is also inter prediction.

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

3.36 **intra prediction**: A *prediction* derived from only data elements (e.g., sample values) of the same decoded *slice* without referring to a *reference picture*.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.48 **non-IDR picture**: A *coded picture* that is not an *IDR picture*.

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

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

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

3.52 **parameter**: A *syntax element* of an *SPS* or *PPS*, or the second word of the defined term *quantization parameter*.

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

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

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

3.55 **picture parameter set (PPS)**: A *syntax structure* containing *syntax elements* that apply to zero or more entire *coded pictures* as determined by a *syntax element* found in each *slice header*.

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

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

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

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

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

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3.61 **profile**: A specified subset of the syntax of this document.

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

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

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

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

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

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

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

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

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

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

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

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

3.72 **reserved**: A term that may be used to specify that some values of a particular *syntax element* are for future use by ISO/IEC and shall not be used in *bitstreams* conforming to this version of this document, but may be used in bitstreams conforming to future extensions of this document by ISO/IEC.

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

3.74 **shall**: A term used to express mandatory requirements for conformance to this document.

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

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

3.76 **should**: A term used to refer to the behaviour of an implementation that is encouraged to be followed under anticipated ordinary circumstances, but is not a mandatory requirement for conformance to this document.

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

3.78 **string of data bits (SODB)**: A sequence of some number of bits representing *syntax elements* present within a *raw byte sequence payload* prior to the *raw byte sequence payload stop bit*, where the left-most bit is considered to be the first and most significant bit, and the right-most bit is considered to be the last and least significant bit.

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

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

3.81 **tile**: A rectangular region of *CTUs* within a particular *tile column* and a particular *tile row* in a *picture*.

3.82 **tile column**: A rectangular region of *CTUs* having a height equal to the height of the *picture* and width specified by *syntax elements* in the *PPS*.

3.83 **slice**: An integer number of *tiles* of a *picture* in the tile raster scan of the *picture* and that are exclusively contained in a single *NAL unit*.

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3.84 **slice header**: A part of a coded *slice* containing the data elements pertaining to the first or all *tiles* represented in the *slice*.

3.85 **tile row**: A rectangular region of *CTUs* having a height specified by *syntax elements* in the *PPS* and a width equal to the width of the *picture*.

3.86 **tile scan**: A specific sequential ordering of *CTUs partitioning* a *picture* in which the *CTUs* are ordered consecutively in *CTU raster scan* in a *tile* whereas *tiles* in a *picture* are ordered consecutively in a *raster scan* of the *tiles* of the *picture*.

3.87 **transform block**: A rectangular MxN *block* of samples resulting from a *transform* in the *decoding process*.

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

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

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

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

4 Abbreviations

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

APS	Adaptation Parameter Set
ATS	Adaptive Transform Selection
B	Bi-predictive
CBR	Constant Bit Rate
CPB	Coded Picture Buffer
CTB	Coding Tree Block
CTU	Coding Tree Unit
CVS	Coded Video Sequence
DPB	Decoded Picture Buffer
HRD	Hypothetical Reference Decoder
HSS	Hypothetical Stream Scheduler
I	Intra
IDR	Instantaneous Decoding Refresh
LSB	Least Significant Bit
LTRP	Long-Term Reference Picture
MMVD	Merge with Motion Vector Difference
MSB	Most Significant Bit
NAL	Network Abstraction Layer
P	Predictive
POC	Picture Order Count
PPS	Picture Parameter Set
QP	Quantization Parameter
RBSP	Raw Byte Sequence Payload
RGB	Same as GBR
SAR	Sample Aspect Ratio
SEI	Supplemental Enhancement Information
SODB	String Of Data Bits
SPS	Sequence Parameter Set

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STRP	Short-Term Reference Picture
VBR	Variable Bit Rate
VCL	Video Coding Layer

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5 Conventions

5.1 General

NOTE – The mathematical operators used in this document are similar to those used in the C programming language. However, the results of integer division and arithmetic shift operations are defined more precisely, and additional operations are defined, such as exponentiation and real-valued division. Numbering and counting conventions generally begin from 0, e.g., "the first" is equivalent to the 0-th, "the second" is equivalent to the 1-th, etc.

5.2 Arithmetic operators

The following arithmetic operators are defined as follows:

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

5.3 Logical operators

The following logical operators are defined as follows:

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

5.4 Relational operators

The following relational operators are defined as follows:

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

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

5.5 Bit-wise operators

The following bit-wise operators are defined as follows:

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

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