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# Information technology — JPEG XL image coding system

## Part 1: Core coding system

*Technologies de ~~l'information~~ l'information — Système de codage ~~d'images~~d'images JPEG XL*

*Partie 1: Système de codage de noyau*



FDIS stage

## Contents

## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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

This second edition cancels and replaces the first edition (ISO/IEC 18181-1:2022), which has been technically and editorially revised.

The main changes are as follows:

— technical corrections and clarifications, in particular to correct the values of various constants, correct errors in pseudocode, and clarify ambiguities in order to remove discrepancies between this part of the ISO/IEC 18181 series and parts 3 and 4;

— a thorough update of the document structure in order to improve clarity of presentation and to obtain a more logical ordering of the material from the point of view of decoder implementation.

A list of all parts in the ISO/IEC 18181 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

# Information technology - — JPEG XL image coding system — —

# Part 1:
# Core coding system

## 1 1Scope

This document specifies a set of compression methods for coding one or more images of bi-level, continuous-tone greyscale, or continuous-tone colour, or multichannel digital samples.

This document:

— —specifies decoding processes for converting compressed image data to reconstructed image data;

— —specifies a codestream syntax containing information for interpreting the compressed image data;

— —provides guidance on encoding processes for converting source image data to compressed image data.

## 2 2Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15076-2[1], *Image technology colour management — Architecture, profile format and data structure — Part 2: Based on ICC.1:2022*

ISO/IEC 60559, *Information technology — Microprocessor Systems — Floating-Point arithmetic*

IEC 61966-2-1, *Multimedia systems and equipment — Colour measurement and management — Part 2-1: Colour management — Default RGB colour space — sRGB*

~~ISO/AWI 15076-2, *Image technology colour management — Architecture, profile format and data structure — Part 2: Based on ICC.1:2022*~~

ITU-R BT.2100-2, *Image parameter values for high dynamic range television for use in production and international programme exchange*. ~~Available from: https://extranet.itu.int/brdocsearch/_layouts/15/DocSetHome.aspx?id=/brdocsearch/R-REC/R-REC-BT/R-REC-BT.2100/R-REC-BT.2100-2-201807-I~~.

ITU-R BT.709-6, *Parameter values for the HDTV standards for production and international programme exchange*. ~~Available from: https://extranet.itu.int/brdocsearch/_layouts/15/DocSetHome.aspx?id=/brdocsearch/R-REC/R-REC-BT/R-REC-BT.709/R-REC-BT.709-6-201506-I~~.

IETF RFC 7932:2016, *Brotli Compressed Data Format*

SMPTE ST 428-1, *D-Cinema Distribution Master — Image Characteristics*

~~ISO/IEC 60559, *Information technology — Microprocessor Systems — Floating-Point arithmetic*~~

[1] Under development. Stage at the time of publication: ISO/DIS 15076-2:2024.

~~IETF RFC 7932:2016, *Brotli Compressed Data Format*~~

# 43 ~~3~~Terms, definitions and abbreviated terms

## 4.13.1~~3.1~~ Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org

**3.1.1**
**bitstream**
sequence of bytes

**3.1.2**
**codestream**
bitstream representing compressed image data

**3.1.3**
**bundle**
structured data consisting of one or more fields

**3.1.4**
**field**
numerical value or bundle, or an array of either

**3.1.5**
**histogram**
array of unsigned integers representing a probability distribution, used for entropy coding



## 4.23.2~~3.2~~ Inputs

**3.2.1**
**pixel**
vector of dimension corresponding to the number of channels, consisting of samples

**3.2.2**
**sample**
integer or real value, of which there is one per channel per pixel

**3.2.3**
**grid**
2-dimensional array

**3.2.4**
**sample grid**
common coordinate system for all samples of an image, with top-left coordinates (0, 0), the first coordinate increasing towards the right, and the second increasing towards the bottom

**3.2.5**
**channel component**
rectangular array of samples having the same designation, regularly aligned along a sample grid

**3.2.6**
**rectangle**
rectangular area within a channel or grid

**3.2.7**
**width**
width in samples (number of columns) of a sample grid or a rectangle

**3.2.8**
**height**
height in samples (number of rows) of a sample grid or a rectangle

**3.2.9**
**frame**
single image (possibly part of an animation, composite, or multi-page image), i.e. a 2-dimensional array of pixels

**3.2.10**
**greyscale**
image representation in which each pixel is defined by a single sample representing intensity (either luminance or luma depending on the ICC profile)



**3.2.11**
**opsin**
photosensitive pigments in the human retina, having dynamics approximated by the XYB colour space

**3.2.12**
**animation**
series of pictures and timing delays to display as a video medium



**3.2.13**
**tick**
unit of time such that animation frame durations are integer multiples of the tick duration

**3.2.14**
**composite**
series of images that are superimposed

**3.2.15**
**multi-page image**
sequence of pictures to display in a paged way

**3.2.16**
**preview**
lower-fidelity rendition of one of the frames (e.g., lower resolution), or a frame that represents the entire content of all frames

## ~~4.~~3.3 ~~3.3~~ Processes

**3.3.1**
**decoding process**
process which takes as its input a codestream and outputs an image

**3.3.2**
**decoder**
embodiment of a decoding process

**3.3.3**
**encoding process**
process which takes as its input image(s) and outputs compressed image data in the form of a codestream

**3.3.4**
**encoder**
embodiment of an encoding process

**3.3.5**
**lossless**
descriptive term for encoding and decoding processes in which the output of a decoding procedure is identical to the input to the encoding procedure

**3.3.6**
**lossy**
descriptive term for encoding and decoding processes which are not lossless

**3.3.7**
**upsampling**
procedure by which the (nominal) spatial resolution of a channel is increased

**3.3.8**
**downsampling**
procedure by which the spatial resolution of a channel is reduced

**3.3.9**
**entropy encoding**
lossless procedure designed to convert a sequence of input symbols into a sequence of bits such that the average number of bits per symbol approaches the entropy of the input symbols

**3.3.10**
**entropy encoder**
embodiment of an entropy encoding procedure

**3.3.11**
**entropy decoding**
lossless procedure which recovers the sequence of symbols from the sequence of bits produced by the entropy encoder

**3.3.12**
**entropy decoder**
embodiment of an entropy decoding procedure

**3.3.13**
**channel decorrelation**
method of reducing total encoded entropy by removing correlations between channels

**3.3.14**
**channel correlation factor**
factor by which a channel should be multiplied by before adding it to another channel to undo the channel decorrelation process

**3.3.15**
**VarDCT**
lossy encoding of a frame that applies DCT to varblocks

**3.3.16**
**quantization**
method of reducing the precision of (DCT) coefficients

**3.3.17**
**quantization weight**
factor that a quantized coefficient is multiplied by prior to application of the inverse DCT in the decoding process

## ~~4.4~~3.4 ~~3.4~~ Image and codestream organization

**3.4.1**
**raster order**
access pattern from left to right in the top row, then in the row below and so on

**3.4.2**
**naturally aligned**
positioning of a power-of-two sized rectangle such that its top and left coordinates are divisible by its width and height, respectively

**3.4.3**
**block**
naturally aligned square rectangle covering up to 8 × 8 input pixels

**3.4.4**
**varblock**
variable-size rectangle of one or more blocks

**3.4.5**
**group**
naturally aligned rectangle covering up to $2^n \times 2^n$ input pixels, with n between 7 and 10, inclusive

**3.4.6**
**table of contents**
data structure that enables seeking to a group or the next frame within a codestream

**3.4.7**
**section**
part of the codestream with an offset and length that are stored in a frame's table of contents

**3.4.8**
**coefficient**
input value to the inverse DCT

**3.4.9**
**pass**
data enabling decoding of successively more detail

**3.4.10**
**LF group**
LF values from a naturally aligned rectangle covering up to $2^{n+3} \times 2^{n+3}$ input pixels

## 4.53.53.5 Abbreviated terms

| | |
|---|---|
| DCT | discrete cosine transform (as specified in I.7I.7) |
| HF | all DCT coefficients apart from the LF coefficients, i.e. the high frequency coefficients |
| IDCT | inverse discrete cosine transform (as specified in I.7I.7) |
| LF | lowest frequency coefficients of DCT coefficients, i.e. block averages |
| RGB | additive colour model with red, green, blue channels |
| XYB | absolute colour space based on gamma-corrected LMS (a colour space representing the response of cone cells in the human eye), in which X is derived from the difference between L and M (red-green), Y is an average of L and M (behaves similarly to luminance), and B is derived from S (blue) |



# 54 4Conventions

## 5.14.14.1 Mathematical symbols

| | |
|---|---|
| [a, b], (c, d), [e, f] | closed or open or half-open intervals containing all integers or real numbers x (depending on context) such that $a \leq x \leq b$, $c < x < d$, $e \leq x < f$ |
| {a, b, c} | ordered sequence of elements |
| pi | the smallest positive zero of the sine function ($\pi$) |

## 5.24.24.2 Functions

| | |
|---|---|
| `pow(x,y)` | exponentiation, `x` to the power of `y`. |
| `sqrt(x)` | square root, such that `pow(sqrt(x),2) == x` and `sqrt(x) >= 0`. Undefined for `x < 0`. |
| `cbrt(x)` | cube root, such that `pow(cbrt(x),3) == x`. |
| `cos(r)` | cosine of the angle `r` (in radians). |
| `erf(x)` | Gauss error function: `erf(x)` $= \frac{2}{\sqrt{\pi}} \int_0^x e^{-t^2} dt$ |
| `log(x)` | natural logarithm of `x`. Undefined for `x <= 0`. |
| `log2(x)` | base-two logarithm of `x`. Undefined for `x <= 0`. |
| `floor(x)` | the largest integer that is less than or equal to `x`. |
| `ceil(x)` | the smallest integer that is greater than or equal to `x`. |
| `abs(x)` | absolute value of `x`: equal to `-x` if `x < 0`, otherwise `x`. |

| | |
|---|---|
| `sign(x)` | sign of `x`, 0 if `x` is 0, +1 if `x` is positive, −1 if `x` is negative. |
| `len(a)` | length (number of elements) of array `a`. |
| `sum(a)` | sum of all elements of the array/tuple/sequence `a`. |
| `max(a)` | maximal element of the array/tuple/sequence `a`. |
| `min(a)` | smallest element of the array/tuple/sequence `a`. |
| `UnpackSigned(u)` | equivalent to `u/2` if `u` is even, and `-(u + 1)/2` if `u` is odd. |
| `clamp(x, lo, hi)` | equivalent to `min(max(lo, x), hi)`. |
| `InterpretAsF16(u)` | the real number resulting from interpreting the unsigned 16-bit integer `u` as a binary16 floating-point number representation (cf. ISO/IEC ~~/IEEE~~ 60559) |
| `InterpretAsF32(u)` | the real number resulting from interpreting the unsigned 32-bit integer `u` as a binary32 floating-point number representation (cf. ISO/IEC ~~/IEEE~~ 60559) |
| `NarrowToI32(x)` | the signed 32-bit integer corresponding to the 32 least significant bits of the two's complement representation of `x` |
| `BitSet(u,b)` | the bit corresponding to `b` is 1 in `u`: true if and only if `u & b` (bitwise AND) |

### ~~5.3~~4.3 ~~4.3~~ Operators

This document uses the operators defined by the C++ programming language ~~(ISO/IEC 14882),~~(ISO/IEC 14882), with the following differences:

| | |
|---|---|
| `/` | division of real numbers without truncation or rounding. Division by zero is undefined. |
| `<<` | left shift: `x << s` is defined as `x * pow(2,s)` |
| `>>` | right shift: `x >> s` is defined as `floor(x / pow(2,s))` |
| `Umod` | remainder: `a Umod d` is the unique integer `r` in `[0, d)` for which `a == r + q * d` for a suitable integer `q` |
| `Idiv` | integer division: `a Idiv b` is equivalent to `a / b`, rounded towards zero to an integer value |
| `and` | logical AND (`&&` in C++), true if and only if both operands are true, with short-circuit evaluation |
| `or` | logical OR (`\|\|` in C++), false if and only if both operands are false, with short-circuit evaluation |

The order of precedence for these operators is listed in ~~Table 1~~Table 1 in descending order. If several operators appear in the same line, they have equal precedence. When several operators of equal precedence appear at the same level in an expression, evaluation proceeds according to the associativity of the operator (either from right to left or from left to right).

**Table ~~1~~ 1 — Operator precedence**

| Operators | Type of operation | Associativity |
|---|---|---|
| `++x`, `--x` | prefix increment/decrement | left to right |
| `x++`, `x--` | postfix increment/decrement | left to right |
| `!`, `~` | logical/bitwise NOT | right to left |
| `*`, `/`, `Idiv`, `Umod` | multiplication, division, integer division, remainder | left to right |
| `+`, `-` | addition and subtraction | left to right |

| Operators | Type of operation | Associativity |
|---|---|---|
| <<, >> | left shift and right shift | left to right |
| < , >, <=, >=, ==, != | relational | left to right |
| & | bitwise AND | left to right |
| ^ | bitwise XOR | left to right |
| \| | bitwise OR | left to right |
| and | logical AND | left to right |
| or | logical OR | left to right |
| = | assignment | right to left |
| +=, −=, *= | compound assignment | right to left |

### ~~5.4~~4.4.4 ~~4.4~~ Pseudocode

This document describes functionality using pseudocode formatted as follows:

```
// Informative comment
var = u(8);
if (var == 1) return;  // Stop executing this code snippet
/* Normative specification: var != 0 */
(out1, out2) = Function(var, kConstant);
```

Variables such as `var` are typically referenced by text outside the source code.

The semantics of this pseudocode are those of the C++ programming language ~~(ISO/IEC 14882),~~(ISO/IEC 14882), except that:

— ~~—~~Symbols from ~~4.1~~4.1 and functions from ~~4.2~~4.2 are allowed;

— ~~—~~Division, remainder and exponentiation are expressed as specified in 4.3;

— ~~—~~Functions can return tuples which unpack to variables as in the above example;

— ~~—~~`/* */` enclose normative directives specified using prose;

— ~~—~~All integers are stored using two's complement;

— ~~—~~Expressions and variables of which types are omitted, are understood as real numbers.

Where unsigned integer wraparound and truncated division are required, `Umod` and `Idiv` (see 4.3) are used for those purposes.

## ~~6~~5 ~~5~~Functional concepts

### ~~6.1~~5.1 ~~5.1~~ Image organization

A channel is defined as a rectangular array of (integer or real) samples regularly aligned along a sample grid of `width` sample positions horizontally and `height` sample positions vertically. The number of channels may be 1 to 4099 (see `num_extra` in D.3).

A pixel is defined as a vector of dimension corresponding to the number of channels, consisting of samples with a position matching that of the pixel.

Field Code Changed

Field Code Changed

Field Code Changed