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**Information technology — Scalable  
compression and coding of  
continuous-tone still images —**

**Part 7:  
HDR Floating-Point Coding**

*Technologies de l'information — Compression échelonnable et codage  
d'images plates en ton continu —*

*Partie 7: Codage de la virgule flottante en HDR*

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## Foreword

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

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](http://www.iso.org/directives)).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

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

This second edition cancels and replaces the first edition (ISO 18477-7:2016), of which it constitutes a minor revision. The changes compared to the previous edition are as follows:

- a definition has been added for the term “horizontal subsampling factor” as [3.1.31](#);
- notes to entry have been added to terms throughout [Clause 3](#);
- text in [F.3](#) and [F.4.2](#) has been modified;
- minor editorial changes.

A list of all the parts in the ISO/IEC 18477 series can be found on the ISO website.

## Introduction

This document specifies a coded codestream format for storage of continuous-tone high and low dynamic range photographic content. JPEG XT part 7 is a scalable image coding system supporting multiple component images consisting of floating-point samples. It is by itself an extension of the coding tools defined in ISO/IEC 18477-1 and the box-based format defined in ISO/IEC 18477-3; the codestream is composed in such a way that legacy applications conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1 are able to reconstruct a lower quality, low dynamic range, eight bits per sample version of the image. This standard low dynamic range image is typically constructed at the encoder side by tone mapping from the high dynamic image; while the LDR image is always present, this document does not define a process that generates this image.

Today, the most widely used digital photography format, a minimal implementation of JPEG (specified in Rec. ITU-T T.81 | ISO/IEC 10918-1), uses a bit depth of 8; each of the three channels that together compose an image pixel is represented by eight bits, providing 256 representable values per channel. If the dynamic range of the input scene is too large, however, an integer sample representation is no longer applicable and sample values need to be specified in floating-point. These values typically are, or are proportional to physical radiance values of three primaries. These primaries may be device specific physical colours, or may be the basis of the CIE XYZ colour space.

JPEG XT is primarily designed to provide coded data containing high dynamic range and wide colour gamut content while simultaneously providing eight bits per pixel low dynamic range images using tools defined in ISO/IEC 18477-1. The goal is to provide a backwards compatible coding specification that allows legacy applications and existing tool chains to continue to operate on codestreams conforming to this document.

JPEG XT has been designed to be backwards compatible to legacy applications while at the same time having a small coding complexity; JPEG XT uses, whenever possible, functional blocks of Rec. ITU-T T.81 | ISO/IEC 10918-1 to extend the functionality of the legacy JPEG Coding System. It is optimized for storage and transmission of high dynamic range and wide colour gamut floating-point images while also enabling low-complexity encoder and decoder implementations.

This document is an extension of ISO/IEC 18477-1, a compression system for continuous-tone digital still images which is backwards compatible with Rec. ITU-T T.81 | ISO/IEC 10918-1. That is, legacy applications conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1 will be able to reconstruct streams generated by an encoder conforming to this document, though will possibly not be able to reconstruct such streams in full dynamic range, full quality or other features defined in this document.

This document is itself based on ISO/IEC 18477-3, which defines a box-based file format similar to other JPEG standards. The aim of this document is to provide a migration path for legacy applications to support, potentially in a limited way, lossless coding and coding of high dynamic range images consisting of samples represented in floating-point. Existing tools depending on the existing standards will continue to work, but will only be able to reconstruct a lossy and/or a low dynamic range version of the image contained in the codestream. This document specifies a coded file format, referred to as JPEG XT, which is designed primarily for storage and interchange of continuous-tone photographic content

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# Information technology — Scalable compression and coding of continuous-tone still images —

## Part 7: HDR Floating-Point Coding

### 1 Scope

This document specifies a coding format, referred to as JPEG XT, which is designed primarily for continuous-tone photographic content.

### 2 Normative 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/IEC 18477-1:2015, *Information technology — Scalable compression and coding of continuous-tone still images — Part 1: Scalable compression and coding of continuous-tone still images*

ISO/IEC 18477-2, *Information technology — Scalable compression and coding of continuous-tone still images — Part 2: Coding of high dynamic range images*

ISO/IEC 18477-3:2015, *Information technology — Scalable compression and coding of continuous-tone still images — Part 3: Box file format*

ISO/IEC 18477-6:2016, *Information technology — Scalable compression and coding of continuous-tone still images — Part 6: IDR Integer Coding*

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

Rec. ITU-T T.81 | ISO/IEC 10918-1:1994, *Information technology — Digital compression and coding of continuous-tone still images — Requirements and guidelines*

Rec. ITU-T BT.601, *Studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios*

### 3 Terms, definitions, symbols and abbreviated terms

#### 3.1 Terms and definitions

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

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

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 3.1.1

#### **ASCII encoding**

encoding of text characters and text strings according to ISO/IEC 10646

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.2

#### **base decoding path**

process of decoding legacy codestream and refinement data to the base image, jointly with all further steps until residual data is added to the values obtained from the residual codestream

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.3

#### **base image**

collection of sample values obtained by entropy decoding the DCT coefficients of the legacy codestream and the refinement codestream, and inversely DCT transforming them jointly

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.4

#### **binary decision**

choice between two alternatives

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.5

#### **bitstream**

partially encoded or decoded sequence of bits comprising an entropy-coded segment

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.6

#### **block**

$8 \times 8$  array of samples or an  $8 \times 8$  array of DCT coefficient values of one component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.7

#### **box**

structured collection of data describing the image or the image decoding process embedded into one or multiple APP<sub>11</sub> marker segments

Note 1 to entry: See ISO/IEC 18477-3:2015, Annex B.

### 3.1.8

#### **byte**

group of 8 bits

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.9

#### **coder**

embodiment of a coding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.10

#### **coding**

encoding or decoding

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.11 coding model

procedure used to convert input data into symbols to be coded

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.12 (coding) process

general term for referring to an encoding process, a decoding process, or both

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.13 compression

reduction in the number of bits used to represent source image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.14 component

two-dimensional array of samples having the same designation in the output or display device

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

Note 2 to entry: An image typically consists of several components, e.g. red, green and blue.

### 3.1.15 continuous-tone image

image whose components have more than one bit per sample

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.16 data unit

$8 \times 8$  block of samples of one component in DCT-based processes; a sample in lossless processes

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.17 decoder

embodiment of a decoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.18 decoding process

process which takes as its input compressed image data and outputs a continuous-tone image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.19 dequantization

inverse procedure to quantization by which the decoder recovers a representation of the DCT coefficients

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.20 discrete cosine transform DCT

either the forward discrete cosine transform or the inverse discrete cosine transform

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.21**

**downsampling**

procedure by which the spatial resolution of a component is reduced

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.22**

**encoder**

embodiment of an encoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.23**

**encoding process**

process which takes as its input a continuous-tone image and outputs compressed image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.24**

**entropy-coded (data) segment**

independently decodable sequence of entropy encoded bytes of compressed image data

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.25**

**entropy decoder**

embodiment of an entropy decoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.26**

**entropy decoding**

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

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.27**

**entropy encoder**

embodiment of an entropy encoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.28**

**entropy encoding**

lossless procedure which converts 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

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.29**

**grayscale image**

continuous-tone image that has only one component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.30**

**high dynamic range**

image or image data comprised of samples using a floating-point representation

**3.1.31****horizontal subsampling factor**

relative number of vertical data units of a particular component with respect to the number of horizontal data units in the other components in the frame

Note 1 to entry: See ISO/IEC 18477-1.

**3.1.32****Huffman decoder**

embodiment of a Huffman decoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.33****Huffman decoding**

entropy decoding procedure which recovers the symbol from each variable length code produced by the Huffman encoder

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.34****Huffman encoder**

embodiment of a Huffman encoding procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.35****Huffman encoding**

entropy encoding procedure which assigns a variable length code to each input symbol

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.36****joint photographic experts group****JPEG**

informal name of the committee which created this document

Note 1 to entry: The “joint” comes from the ITU-T and ISO/IEC collaboration.

**3.1.37****legacy codestream**

collection of markers and syntax elements defined by Rec. ITU-T T.81 | ISO/IEC 10918-1 bare any syntax elements defined by the family ISO/IEC 18477 standards

EXAMPLE The legacy codestream consists of the collection of all markers except those APP<sub>11</sub> markers that describe JPEG XT boxes by the syntax defined in ISO/IEC 18477-3, Annex A.

Note 1 to entry: See ISO/IEC 18477-6.

**3.1.38****legacy decoder**

embodiment of a decoding process conforming to Rec. ITU-T T.81 | ISO/IEC 10918-1, confined to the lossy DCT process and the baseline, sequential or progressive modes, decoding at most four components to eight bits per component

Note 1 to entry: See ISO/IEC 18477-6.

**3.1.39****lossless**

descriptive term for encoding and decoding processes and procedures in which the output of the decoding procedure(s) is identical to the input to the encoding procedure(s)

Note 1 to entry: See ISO/IEC 18477-8.

**3.1.40**

**lossless coding**

mode of operation which refers to any one of the coding processes defined in this document in which all of the procedures are lossless

Note 1 to entry: See ISO/IEC 18477-8.

**3.1.41**

**lossy**

descriptive term for encoding and decoding processes which are not lossless

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.42**

**low dynamic range**

image or image data comprised of data with no more than eight bits per sample

Note 1 to entry: See ISO/IEC 18477-6.

**3.1.43**

**marker**

two-byte code in which the first byte is hexadecimal FF and the second byte is a value between 1 and hexadecimal FE

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.44**

**marker segment**

marker together with its associated set of parameters

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.45**

**pixel**

collection of sample values in the spatial image domain having all the same sample coordinates

Note 1 to entry: A pixel may consist of three samples describing its red, green and blue value.

Note 2 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.46**

**precision**

number of bits allocated to a particular sample or DCT coefficient

**3.1.47**

**procedure**

set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.48**

**quantization value**

integer value used in the quantization procedure

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.49**

**quantize**

act of performing the quantization procedure for a DCT coefficient

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.50 residual decoding path

collection of operations applied to the entropy coded data contained in the residual data box and residual refinement scan boxes up to the point where this data is merged with the base image to form the final output image

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.51 residual image

sample values as reconstructed by inverse quantization and inverse DCT transformation applied to the entropy-decoded coefficients described by the residual scan and residual refinement scans

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.52 residual scan

additional pass over the image data invisible to legacy decoders which provides additive and/or multiplicative correction data of the legacy scans to allow reproduction of high dynamic range or wide colour gamut data

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.53 refinement scan

additional pass over the image data invisible to legacy decoders which provides additional least significant bits to extend the precision of the DCT transformed coefficients

Note 1 to entry: See ISO/IEC 18477-6.

### 3.1.54 sample

one element in the two-dimensional image array which comprises a component

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.55 sample grid

common coordinate system for all samples of an image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

Note 2 to entry: The samples at the top left edge of the image have the coordinates (0,0), the first coordinate increases towards the right, the second towards the bottom.

### 3.1.56 scan

single pass through the data for one or more of the components in an image

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

### 3.1.57 scan header

marker segment that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a scan

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.58**

**table specification data**

coded representation from which the tables used in the encoder and decoder are generated and their destinations specified

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.59**

**(uniform) quantization**

procedure by which DCT coefficients are linearly scaled in order to achieve compression

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.60**

**upsampling**

procedure by which the spatial resolution of a component is increased

Note 1 to entry: See ISO/IEC 18477-1.

**3.1.61**

**vertical subsampling factor**

relative number of vertical data units of a particular component with respect to the number of vertical data units in the other components in the frame

Note 1 to entry: See ISO/IEC 18477-1.

**3.1.62**

**zero byte**

0×00 byte

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.1.63**

**zig-zag sequence**

specific sequential ordering of the DCT coefficients from (approximately) lowest spatial frequency to highest

Note 1 to entry: See Rec. ITU-T T.81 | ISO/IEC 10918-1.

**3.2 Symbols**

X width of the sample grid in positions

Y height of the sample grid in positions

Nf number of components in an image

$s_{i,x}$  subsampling factor of component  $i$  in horizontal direction

$s_{i,y}$  subsampling factor of component  $i$  in vertical direction

$H_i$  subsampling indicator of component  $i$  in the frame header

$V_i$  subsampling indicator of component  $i$  in the frame header

$v_{x,y}$  sample value at the sample grid position  $x,y$

- $R_h$  additional number of DCT coefficient bits represented by refinement scans in the legacy decoding path,  $8 + R_h$  is the number of non-fractional bits (i.e. bits in front of the “binary dot”) of the output of the inverse DCT process in the legacy decoding path
- $R_r$  additional number of DCT coefficient bits represented by refinement scans in the residual decoding path.  $p + R_r$  is the number of non-fractional bits of the output of the inverse DCT process in the residual decoding path, where  $p$  is the frame-precision of the residual image as recorded in the frame header of the residual codestream
- $R_b$  additional bits in the HDR image.  $8 + R_b$  is the sample precision of the reconstructed HDR image

### 3.3 Abbreviated terms

- ASCII American Standard Code for Information Interchange
- LSB Least Significant Bit
- MSB Most Significant Bit
- HDR High Dynamic Range
- LDR Low Dynamic Range
- TMO Tone Mapping Operator
- DCT Discrete Cosine Transformation

## 4 Conventions

### 4.1 Conformance language

This document consists of normative and informative text.

Normative text is that text which expresses mandatory requirements. The word “shall” is used to express mandatory requirements strictly to be followed in order to conform to this document and from which no deviation is permitted. A conforming implementation is one that fulfils all mandatory requirements.

Informative text is text that is potentially helpful to the user, but not indispensable and can be removed, changed or added editorially without affecting interoperability. All text in this document is normative, with the following exceptions: the Introduction, any parts of the text that are explicitly labelled as “informative”, and statements appearing with the preamble “NOTE” and behaviour described using the word “should”. The word “should” is used to describe behaviour that is encouraged but is not required for conformance to this document.

The keywords “may” and “need not” indicate a course of action that is permissible in a conforming implementation.

The keyword “reserved” indicates a provision that is not specified at this time, shall not be used, and may be specified in the future. The keyword “forbidden” indicates “reserved” and in addition indicates that the provision will never be specified in the future.

### 4.2 Operators

NOTE Many of the operators used in this document are similar to those used in the C programming language.

**4.2.1 Arithmetic operators**

- + addition
- subtraction (as a binary operator) or negation (as a unary prefix operator)
- \* multiplication
- / division without truncation or rounding

**4.2.2 Logical operators**

- || Logical OR
- && Logical AND
- ! Logical NOT
- ∈  $x \in \{A, B\}$  is defined as  $(x = A \ || \ x = B)$
- ∉  $x \notin \{A, B\}$  is defined as  $(x \neq A \ \&\& \ x \neq B)$

**4.2.3 Relational operators**

- > greater than
- > = greater than or equal to
- < less than
- < = less than or equal to
- = = equal to
- != not equal to

**4.2.4 Precedence order of operators**

Operators are listed below in descending order of precedence. 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.

Operators	Type of operation	Associativity
() , [] , .	Expression	Left to Right
-	Unary negation	
*, /	Multiplication	Left to Right
+, -	Addition and Subtraction	Left to Right
<, >, < =, > =	Relational	Left to Right

#### 4.2.5 Mathematical functions

$\lceil x \rceil$	Ceil of $x$ . Returns the smallest integer that is greater than or equal to $x$ .
$\lfloor x \rfloor$	Floor of $x$ . Returns the largest integer that is lesser than or equal to $x$ .
$ x $	Absolute value, is $-x$ for $x < 0$ ; otherwise, $x$ .
$\text{sign}(x)$	Sign of $x$ , 0 if $x$ is zero, +1 if $x$ is positive, -1 if $x$ is negative.
$\text{clamp}(x, \text{min}, \text{max})$	Clamps $x$ to the range $[\text{min}, \text{max}]$ : returns $\text{min}$ if $x < \text{min}$ , $\text{max}$ if $x > \text{max}$ or otherwise $x$ .
$x^a$	Raises the value of $x$ to the power of $a$ . $x$ is a non-negative real number, $a$ is a real number. $x^a$ is equal to $\exp(a \cdot \log(x))$ where $\exp$ is the exponential function and $\log()$ the natural logarithm. If $x$ is 0 and $a$ is positive, $x^a$ is defined to be 0.
$\log(x)$	Natural logarithm to the base of $e$ . $\log(x)$ is undefined for non-positive values of $x$ .
$\exp(x)$	The exponential function of $x$ . $\exp(x)$ equals $e^x$ where $e$ is the Euler number. Furthermore, $\exp(\log(x)) = x$ for all positive numbers $x$ .

## 5 General

### 5.1 Overview

The purpose of this clause is to give an informative overview of the elements specified in this document. Another purpose is to introduce many of the terms which are defined in [Clause 3](#). These terms are printed in *italics* upon first usage in this clause.

The following are three elements specified in this document.

- An *encoder* is an embodiment of an *encoding process*. An encoder takes as input *digital source image data* and *encoder specifications* and by means of a specified set of *procedures*, generates as output *codestream*.
- A *decoder* is an embodiment of a *decoding process*. A decoder takes as input a *codestream* and by means of a specified set of *procedures*, generates as output *digital reconstructed image data*.
- The *codestream* is a compressed image data representation which includes all necessary data to allow a (full or approximate) reconstruction of the sample values of a digital image. Additional data might be required that define the interpretation of the sample data, such as colour space or the spatial dimensions of the samples.

### 5.2 High-level overview on JPEG XT ISO/IEC 18477-7 (informative)

This document allows lossy coding of high dynamic range of photographic images in a way that is backwards compatible to Rec. ITU-T T.81 | ISO/IEC 10918-1. Decoders compliant to the latter standard will be able to parse codestreams conforming to this document correctly, albeit only in 8-bit sample precision with a limited dynamic range and potentially a limited colour gamut.

This document includes multiple tools to reach the above functionality, defined in [Annex B](#) and on. A short overview on these coding tools will be given in this subclause; an in-depth specification of the algorithm is given in [Annex A](#).

The syntax of an ISO/IEC 18477-7 compliant codestream is specified in ISO/IEC 18477-3, that is, this document uses a syntax element denoted as “box” to annotate its syntactical elements. The definition of the box syntax element is not repeated here, and readers are referred to ISO/IEC 18477-3 for further details. Additional boxes besides those already specified in ISO/IEC 18477-3 are defined in

ISO/IEC 18477-6:2016, Annex B and in [Annex B](#). In addition, ISO/IEC 18477-6 defines coding tools such as **Refinement Coding**, specified in ISO/IEC 18477-6:2016, Annex D and the **residual codestream** carried by the Residual Data box.

The **Refinement Scan**, specified in ISO/IEC 18477-6:2016, Annex D, increases the bit precision of the DCT coefficients, i.e. it operates in the DCT domain. The mechanism used here is very similar to that of Subsequent Approximation scans specified in Rec. ITU-T T.81 | ISO/IEC 10918-1:1994, Annex G. A legacy baseline, extended or progressive Huffman scan as defined in Annex G of the legacy standard defines the 12 most significant bits of the DCT coefficients. These initial scans are represented in the legacy codestream and are visible for any ISO/IEC 18477-1 compliant decoder. Refinement scans decode now into up to four additional least significant bits in the same way subsequent approximation within Rec. ITU-T T.81 | ISO/IEC 10918-1 decode least significant bits of a progressive scan pattern. The difference between Refinement scans and Subsequent Approximation scans is only that in the latter case, the number of least significant bits is annotated in the scan header of the legacy codestream whereas Refinement scans are hidden from legacy applications and do not alter the scan header of the legacy codestream. Their number is indicated in the Refinement Specification box within the Merging Specification box and not in the legacy codestream.

While Refinement Scans extend the bit precision within the DCT domain by up to four bits, **Residual Scans** extend the sample precision in the spatial (image) domain. While the entropy coded data of Residual Scans is hidden in the Residual Data box from legacy applications, its decoding process is **identical** to that of the legacy data: baseline, extended or progressive Huffman scan decodes the data in the Residual Data box to DCT coefficients, inverse quantization and inverse Discrete Cosine Transformation (DCT) compute from these coefficients the **residual image data**. An image merging process, defined in [Annex A](#), computes from the **precursor image** reconstructed from the legacy codestream and the **residual image** a final HDR output image.

This merging process is depicted in [Figure 1](#). It first performs chroma upsampling to reconstruct a single sample on each point of the sample grid of the base image. Chroma upsampling is specified in ISO/IEC 18477-1:2015, Annex A. It then converts the colour space of the base image first from YCbCr into the Rec. ITU-T BT.601 colour space. Optionally, the luma signal of the LDR image is computed from the BT.601 colour space and used as **pre-scaling** of the chroma signals of the residual. The BT.601 image is optionally transformed again into a wider colour space. For practical reasons, the transformations from YCbCr to BT.601 and from BT.601 into an output colour space are combined into a single linear transformation matrix. This linear transformation is followed by a nonlinear point transformation acting separately on each of the output channels sample by sample. This point transformation can either be seen as an approximate inverse tone mapping operation, or as inverse gamma correction that transforms the nonlinear sample values of the LDR image into sample values proportional to physical radiance. It can either be specified by a parametric curve, or by an explicit lookup table. The output of this decoding path is transformed again by an optional colour transformation into the final HDR colour space forming the **precursor image** which represents a rough imprecise approximation of the final HDR image, already in the correct HDR output colour space.

Processing continues with the decoding of the **residual image**. DCT coefficients of the residual image are decoded from the information in the Residual Data box, and their bit precision is extended by additional refinement scans decoded from the data in the **Residual Refinement box**. Processing proceeds with inverse quantization and inverse DCT transformation. The output undergoes chroma upsampling to generate a single sample per sample grid coordinate. The next processing step performs a nonlinear point transformation on each of the reconstructed channels, separately for each sample, resulting in an error image in a YCbCr type of colour space. Chroma samples are then optionally pre-scaled by a factor that is computed from the luminance value of the LDR image by a **nonlinear pre-scaling map**. Optionally, a **post-scaling factor** is computed from the luminance of the residual image through a **nonlinear post-scaling map**. The post-scaling factor scales a linear HDR image from limited dynamic range to full dynamic range in a later processing stage. Residual samples then undergo an inverse linear decorrelation transformation to map the sample values from the intermediate YCbCr colour space into the target colour space. This transformation is typically identical to the transformation matrix in the base decoding path, but does not need to be. After inverse decorrelation, the residual samples are mapped again by the **residual nonlinear point transformation**. The result of this operation is the **residual image**.

To form the final output image, sample values of the **precursor image** and the **residual image** are added together, plus an offset to make the residual image symmetric around zero. The result of this is scaled by the **post-scaling factor** if the **nonlinear post-scaling** map is present. Results are then clamped to the range of the intermediate range output image and finally processed through the **output conversion**. The output conversion either converts samples from integer to floating-point by a half-exponential map, or uses a table lookup or parametric curve for this conversion.

The detailed specification of the decoding and merging process is found in [Annex A](#).

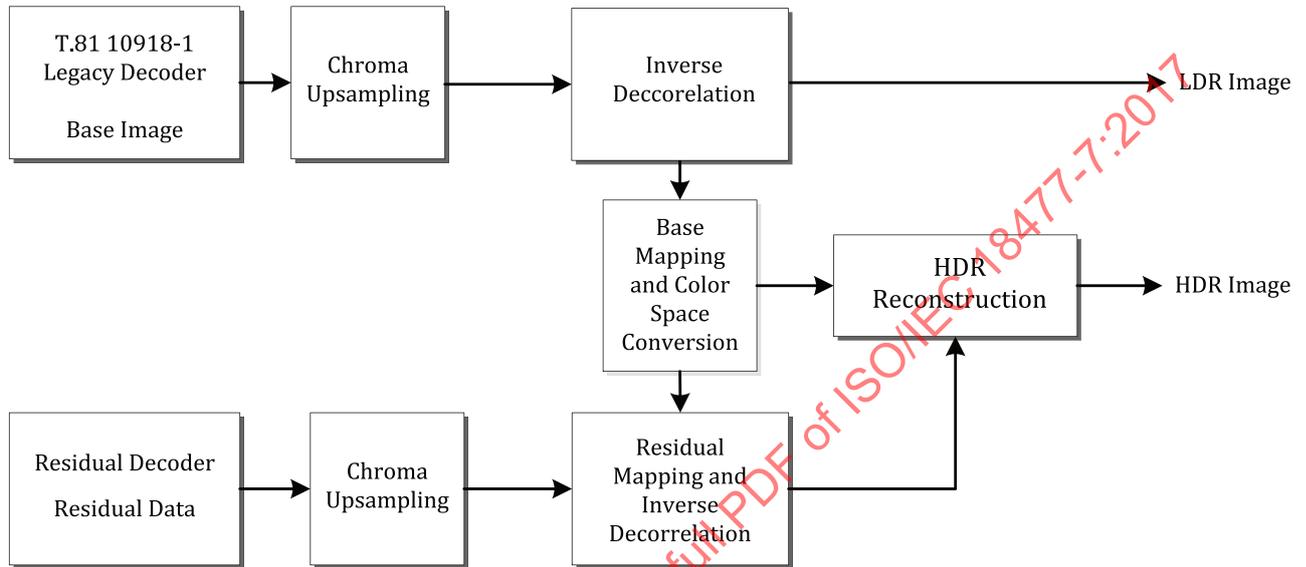


Figure 1 — Overview on the decoding process

### 5.3 Profiles

The profiles define the implementation of a particular technology within the functional blocks of [Figure 1](#). The profiles are described in [Annex E](#).

### 5.4 Encoder requirements

There is **no requirement** in this document that any encoder shall support all profiles. An encoder is only required to meet the compliance tests and to generate the codestream according to the syntax and to limit the coding parameters to those valid within the profile it conforms to. Profiles are defined in [Annex E](#).

### 5.5 Decoder requirements

A decoding process converts compressed image data to reconstructed image data. It **may** follow the decoding operation specified in the Recommendation | International Standard and ISO/IEC 18477-1 to generate an LDR image from the legacy codestream, and it **shall** follow the operations in this document to decode an HDR image from the data in the full file. The decoder shall parse the codestream syntax to extract the parameters, the residual image and the base image. The parameters shall be used to merge the residual image with the base image into the reconstructed HDR Image.

In order to comply with this document, a decoder

- a) **may convert** a codestream conforming to this document **without considering the information in any box** into a low dynamic range image, and
- b) **shall** convert a conforming codestream within the profile it claims to be conforming to into a high dynamic range image.

## Annex A (normative)

### Encoding and decoding process

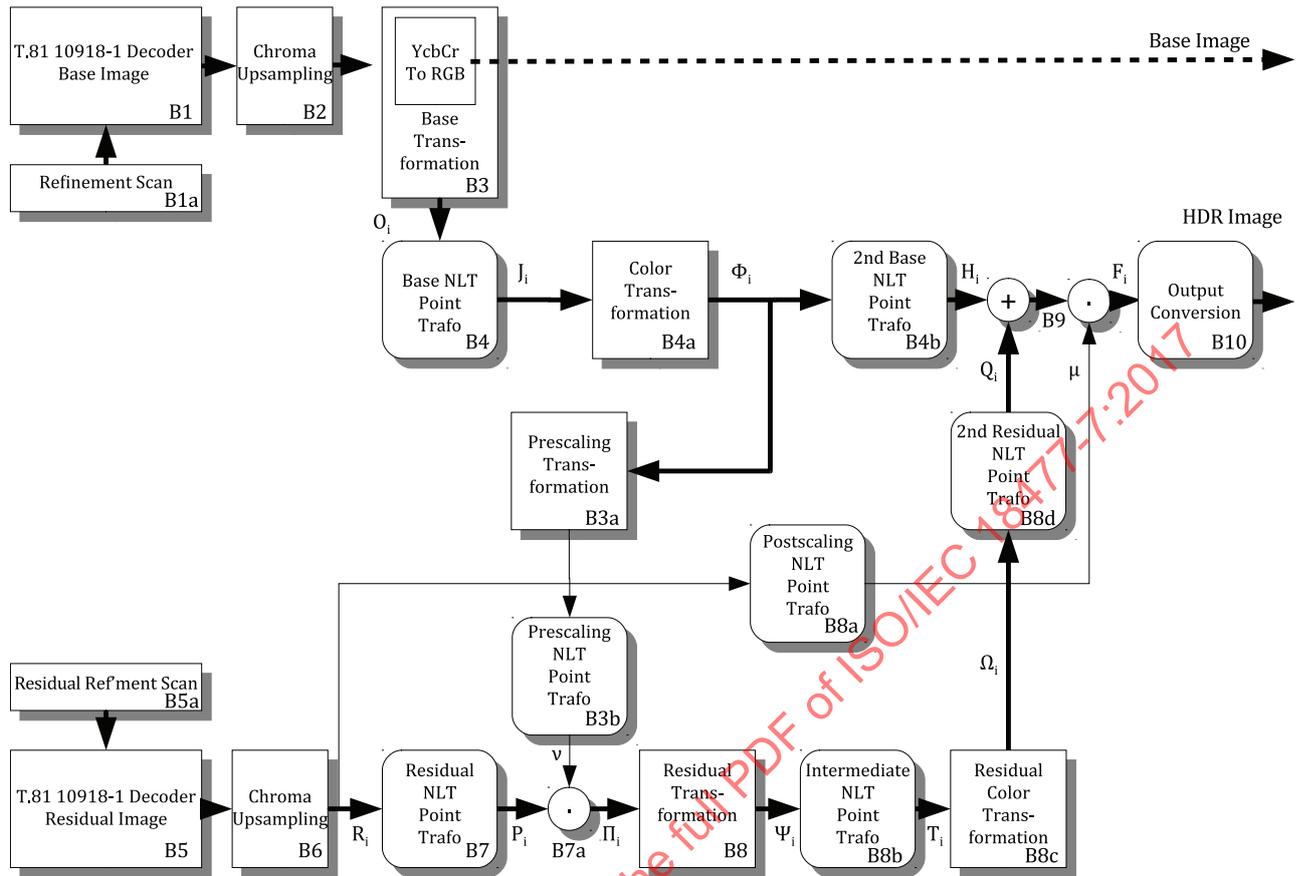
#### A.1 General

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

#### A.2 Decoding process (normative)

The decoding process relies on a layered approach to extend JPEG's capabilities. The encoder decomposes an HDR image into a base layer, which consists of a tone mapped version of the HDR image, and an HDR residual layer. The combination of the data in the residual codestream and the legacy codestream allow the reconstruction of the fully HDR image. Both the metadata describing the merging process and the residual image are included in boxes invisible to legacy decoders. Such decoders will thus only see the tone mapped LDR image. While the base image complies to ISO/IEC 18477-1 and thus supports only the 8-bit extended or baseline, extended or progressive Huffman modes, the residual image may optionally be encoded in the 12-bit Huffman or progressive modes.

[Figure A.1](#) illustrates the functionality of a compliant decoder.



NOTE Bold lines carry three (or one, for grey scale) components, thin lines scalar data. Round boxes implement point-transformations, square boxes (except B1, B1a, B5, B5a) multiplications by  $3 \times 3$  matrices. Letters denote signal names.

**Figure A.1 — High-level overview of the decoding process of a compliant decoder**

This subclause specifies the reconstruction process of an intermediate dynamic range image from a LDR image and residual image decoders shall follow. This process, which is an extension of the process defined in ISO/IEC 18477-6, consists of the following steps (see also [Figure A.1](#)).

- In steps B1 and B1a, reconstruct the base data from legacy codestream and the refinement codestream if a Refinement Data box is present. Refinement coding is specified in ISO/IEC 18477-6:2016, Annex D.
- In step B1 and B1a, apply the Inverse Quantization and Inverse Discrete Cosine Transformation as in Rec. ITU-T T.81 | ISO/IEC 10918-1.
- In step B2, the upsampling process specified in ISO/IEC 18477-1:2015, Annex A shall be followed to generate samples for all positions on the sample grid.
- In step B3, the linear transformation selected by the Base Transformation box defined in ISO/IEC 18477-6:2016, Annex B and Annex C shall be applied to inversely decorrelate the image components. ISO/IEC 18477-6:2016, Table C.1 defines which transformation to pick. The output of this block consists of either one or three samples per grid point  $O_i$ , depending on the number of components in the legacy codestream. The output of this transformation is rounded to integers and clipped to  $[0, 2^{R_h+8}-1]$  where  $R_h$  is the number of refinement scans in the base image, see ISO/IEC 18477-6:2016, Annex D.
- In step B4, a point transformation shall be applied to each of the output components  $O_i$ . This process is selected according to the Base Nonlinear Point Transformation subbox of the Merging Specification box, implementing the Base Nonlinear Point Transformations and following the

specifications of ISO/IEC 18477-3:2015, Annex C. The outputs of this process are the predicted high dynamic range samples  $J_i$ . As above,  $i = 1..N_f$ . The Base Nonlinear Point Transformation box is specified in ISO/IEC 18477-6:2016, Annex B.

- In step B4a, a colour transformation is applied to the input values  $J_i$  resulting in the output pixel values  $H_i$ . The transformation is selected by the Colour Transformation subbox of the Merging Specification box, which selects one of the transformations defined in ISO/IEC 18477-6:2016, Annex C. If  $N_f$  equals one, no transformation is performed. The Colour Transformation box is specified in ISO/IEC 18477-6:2016, Annex B. The output of this step is the linear precursor image samples  $\Phi_i$ .
- In steps B3a and B3b, an optional pre-scaling transformation extracts the luminance from the linear precursor image  $\Phi_i$ . A nonlinear pre-scale map computes from the luminance a **pre-scaling factor**  $v$  that is applied to the reconstructed chroma components  $P_2$  and  $P_3$  according to the procedure described in [B.8](#). The luma value remains unaffected by the scaling process. If the nonlinear pre-scaling map is **not** present, the inferred value of the pre-scale factor shall be 1. The pre-scaling transformation is defined by the **Pre-scale Transformation box**, the nonlinear pre-scale map by the **Pre-scaling Nonlinear Point Transformation box**, both of which are specified in [Annex B](#).
- In step B4b, the **Secondary Base Nonlinear Point Transformation box** applies a nonlinear transformation to the linear precursor image samples  $\Phi_i$  creating the high dynamic range precursor image  $H_i$ . If this box is not present, the high dynamic range precursor image samples  $H_i$  are identical to the linear precursor image  $\Phi_i$ .
- In steps B5 and B5a, the residual image shall be reconstructed from the data contained in the Residual Codestream box and the Residual Refinement box. The codestream contained in this box follows the specifications defined in Rec. ITU-T T.81 | ISO/IEC 10918-1. If a Residual Refinement box is present, the precision of the samples of the residual codestream shall be extended by refinement coding as specified in ISO/IEC 18477-6:2016, Annex D. The number of components of the residual image shall either be equal to the number of components signalled in the base image, or shall be one. If it is one, the inferred chrominance values are  $2^{P-1+R_r}$  where  $P$  is the bit precision of the residual image specified by the frame header of the residual codestream and  $R_r$  the number of residual refinement scans. The  $R_r$  parameter is defined by the Refinement Specification subbox defined in ISO/IEC 18477-6:2016, Annex B.
- In steps B5 and B5a, apply Inverse Quantization and Inverse Discrete Cosine Transformation as in Rec. ITU-T T.81 | ISO/IEC 10918-1.
- In step B6, residual data are upsampled to the common sample grid following the specification of ISO/IEC 18477-1:2015, Annex A, resulting in the Residual Image  $R_i$ .
- In step B7, apply a point transformation to  $R_i$  that is defined by the Residual Point Transformation subbox of the Merging Specification box. The outputs of this operation are three residual sample values per pixel denoted by  $P_i$ .
- In step B7a, the chrominance values of the residual image  $P_i$  are multiplied by the pre-scaling factor  $v$ , giving the pre-scaled values  $\Pi_i$ .
- In step B8, an inverse colour decorrelation shall be applied to the  $\Pi_i$  data. The transformation is defined by the Residual Transformation box, which is a subbox of the Merging Specification box, and is specified in ISO/IEC 18477-6:2016, Annex B. The outputs of this process are the inversely decorrelated prediction errors  $\Psi_i$ .
- In step B8a, a post-scaling factor  $\mu$  is computed through the nonlinear post-scaling map from the luma component of the reconstructed residual image  $R$ . The post-scaling map is defined by the **Post-scaling Nonlinear Point Transformation box** defined in [Annex B](#). If the Post-scaling Nonlinear Point Transformation box is not present, the inferred value of the post-scaling factor  $\mu$  shall be 1.
- In step B8b, the **Intermediate Nonlinear Point Transformation box** defined in [Annex B](#) applies a gamma-correction on the decorrelated prediction errors  $\Psi_i$  generating the gamma-corrected decorrelated prediction errors  $T_i$ . This process is implemented by a Parametric Curve box. If the **Intermediate Nonlinear Point Transformation box** is not present,  $T_i$  equals  $\Psi_i$ .

- In step B8c, the **Residual Colour Transformation box** defined in [Annex B](#) applies an optional transformation of the gamma-corrected decorrelated prediction values  $T_i$  from the source colour space into the target colour space, defining the residual errors  $\Omega_i$ . If the **Residual Colour Transformation box** is not present,  $\Omega_i$  equals  $T_i$ .
- In step B8d, a secondary nonlinear point transformation selected by the **Secondary Residual Nonlinear Point Transformation box** is applied. This box selects for each component a nonlinearity, either a Floating-Point Table Lookup box or a Parametric Curve box that maps the inversely decorrelated residual errors  $\Omega_i$  into the final residual errors  $Q_i$ . If this box is not present,  $Q_i$  is set to  $\Omega_i$ .
- In step B9, the intermediate dynamic range output  $F_i$ , i.e. the output of the decoding process, is reconstructed from  $H_i$ , the predicted high dynamic range signal, and the inversely decorrelation prediction errors  $Q_i$ . The output bit precision  $R_b$  is taken from the Output Conversion subbox of the Merging Specification box defined in [Annex B](#). For this, compute

$$F_i = \mu \cdot (H_i + Q_i \cdot 2^{R_b+8-1})$$

- In step B10, the values  $F_i$  are further processed by the **output conversion** which is specified by the **Output Conversion box**. The output transformation box is defined in [Annex B](#), and is an extension of the Output Transformation box defined in ISO/IEC 18477-6. Output conversion either performs a nonlinear point transformation for each component, or rounds the output to integers, then clamps to the range  $[0, 2^{R_b-1}]$  and then applies a half-exponential integer to floating-point conversion specified in [Annex D](#).

### A.3 Encoding process (informative)

This document does not define a normative encoding process. Any encoding process that generates a file format that is compliant to this document is acceptable as long as this file format reconstructs to the desired image by the normative decoding algorithm.

### A.4 Application notes (informative)

This document specifies a decoding process that is only normative in so far as it defines a decoding process whose output compliant implementations shall replicate. There is no need to follow the decoding process specified in [A.2](#) precisely as long as its output is equivalent to the above. In fact, the above decoding process offers (or many profiles (see [Annex E](#) for their definition) optimization opportunities implementations are encouraged to use.

This subclause is a non-exhaustive list of such opportunities that may lower the complexity of implementations or may lower coding errors due to imperfect implementations of mathematical functions such as  $x^a$ ,  $\log()$  or  $\exp()$ .

- The nonlinear point transformation processes defined by the Parametric Curve box include an input scaling and an output scaling mechanism that ensures that the arguments to the pre-defined functions of the Parametric Curve box are always between 0 and 1. This scaling process is defined in ISO/IEC 18477-3:2015, Annex C. Under some situations, this scaling process can be omitted because the output scaling of a nonlinear transformation cancels with the input scaling of the nonlinear transformation following it in the decoding chain, and the transformation between them is linear, allowing to exchange it with linear scaling. This optimization can be applied to decoding steps B4, B4a, B4b and B8, B8b, B8c, B8d.
- The Output Conversion process together with the addition and the Secondary Base/Residual Nonlinear Point Transformations, i.e. steps B4b, B8d, B9 and B10, can sometimes be accumulated into a single simpler composition process, giving decoders the freedom to merge these four steps into a single step. This happens, for example, for Profile B, see [E.3](#), where the Secondary Base/Residual Nonlinear Point Transformations are logarithmic and the Output Conversion is an exponential map. Implementations may want to optimize these steps into a single division operation. For details, see the informative note at the end of [E.3](#).

- Pre-scaling and post-scaling operations, i.e. the multiplications by  $v$  and  $\mu$  in steps B7a and B9 can be omitted if the decoder can ensure that the scale factors are constant one. This happens, for example, in Profiles B, C and D where the Pre-scaling Nonlinear Transformation box and the Post-scaling Nonlinear Transformation box are absent.

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## Annex B (normative)

### Boxes

#### B.1 General

This annex selects and refines a subset of the boxes defined in ISO/IEC 18477-3 for the purpose of high dynamic range image coding. It lists those boxes of ISO/IEC 18477-3 that are required for this document. All other boxes are optional and its interpretation is outside the scope of this document. Other parts of ISO/IEC 18477 or other standards may define their meaning, and decoders conforming to this document may ignore them.

[Table B.1](#) lists the boxes required in this document that are paired with ISO/IEC 18477-3. Some of the boxes require additional specifications that are listed in subsequent clauses of this annex.

**Table B.1 — Boxes within this document**

Box Name	Box Type	Further definitions in which sub-clause of this document
File Type box	0x66747970 (“ftyp”).	
Legacy Data Checksum box	0x4C43484B (“LCHK”)	
Residual Data box	0x52455349 (“RESI”)	
Residual Refinement box	0x5246494e (“RFIN”)	
Refinement Data box	0x46494e45 (“FINE”)	
Merging Specification box	0x53504543 (“SPEC”)	
Parametric Curve box	0x43555256 (“CURV”)	
Integer Table Lookup box	0x544f4e45 (“TONE”)	
Floating-Point Table Lookup box	0x46544f4e (“FTON”)	
Fix-point Linear Transformation box	0x4D545258 (“MTRX”)	
Floating-point Linear Transformation box	0x46545258 (“FTRX”)	
Output Conversion box	0x4F434F4E (“OCON”)	<a href="#">B.2</a>
Refinement Specification box	0x52535043 (“RSPC”)	
Base Nonlinear Point Transformation Specification box	0x4C505453 (“LPTS”)	<a href="#">B.3</a>
Secondary Base Nonlinear Point Transformation Specification box	0x52505453 (“CPTS”)	<a href="#">B.4</a>
Residual Nonlinear Point Transformation Specification box	0x5152505453 (“QPTS”)	<a href="#">B.5</a>
Intermediate Residual Nonlinear Point Transformation Specification box	0x44505453 (“DPTS”)	<a href="#">B.6</a>
Secondary Residual Nonlinear Point Transformation Specification box	0x52505453 (“RPTS”)	<a href="#">B.7</a>
Pre-scaling Nonlinear Point Transformation Specification box	0x53505453 (“SPTS”)	<a href="#">B.8</a>
Post-scaling Nonlinear Point Transformation box	0x50505453 (“PPTS”)	<a href="#">B.9</a>

Table B.1 (continued)

Box Name	Box Type	Further definitions in which sub-clause of this document
Base Transformation box	0x4C545246 ("LTRF")	<a href="#">B.10</a>
Residual Transformation box	0x52545246 ("RTRF")	<a href="#">B.11</a>
Colour Transformation box	0x43545246 ("CTRF").	<a href="#">B.12</a>
Residual Colour Transformation box	0x44545246 ("DTRF")	<a href="#">B.13</a>
Pre-scaling Transformation box	0x53545246 ("STRF")	<a href="#">B.14</a>

## B.2 Output Conversion box

This mandatory box defines the conversion process from the result of the base image/residual image merging process to the final floating-point samples. It describes the final merging process and by that step B10 of the algorithm described in [A.2](#). This box is already defined in ISO/IEC 18477-3:2015, Annex B, though its application to this document further constraints the value of its fields.

This box shall never appear top level in the file, but it shall be a subbox of the Merging Specification box defined in ISO/IEC 18477-3:2015, Annex B. Exactly one Output Conversion box shall appear in the Merging Specification box if a Merging Specification box exists.

[Table B.2](#) constraints the parameters of the Output Conversion box as applied in this document.

The detailed list of operations to be performed by the output conversion is specified in ISO/IEC 18477-3:2015, Annex B.

Table B.2 — Parameter constraints for the Output Conversion box

Parameter	Constraints within this Recommendation   International Standard	Meaning
$R_b$	8	The value of this field shall be eight. Number of additional bits available for high dynamic range data. The bit precision of the reconstructed high dynamic range image shall be computed as $8 + R_b = 16$ .
$L_f$	0	The value of this field shall be 0. This field indicates whether the compression is lossy or lossless. ISO/IEC 18477-7 only specifies lossy coding. Decoders may use this field to decide whether to follow the DCT specification of ISO/IEC 18477-8 precisely or whether a customized DCT implementation is acceptable.
$O_c$	0..1	Half-exponential output-enable flag. If this flag is set, the output of the merging step shall be rounded to the nearest integer, then clipped, and the half-exponential map defined in <a href="#">Annex D</a> shall be applied. The value of this flag shall be identical to the value of the $C_e$ flag which controls clipping of output values. If the $O_c$ flag is 1, the $O_l$ flag shall be 0. See <a href="#">Table B.3</a> for a detailed definition of output conversion.
$C_e$	0..1	This field indicates whether the output shall be clipped to range $[0, 2^{8+R_b}-1]$ if $O_c$ is 0, or clipped to $[-0x7bff, 0x7bff]$ if $O_c$ is 1 before processing the data further. The value of this flag shall be identical to the value of the $O_c$ flag.

Table B.2 (continued)

Parameter	Constraints within this Recommendation   International Standard	Meaning
O <sub>l</sub>	0..1	This field indicates whether an output lookup or point transformation is required. If so, output shall be processed further by a nonlinear point transformation defined by the to <sub>i</sub> parameters. This flag shall be 0 whenever the O <sub>c</sub> flag is 1.
to <sub>0</sub>	0..15	This field selects the output point transformation for component 0 if O <sub>l</sub> is set. It selects the Floating-Point Table Lookup box or a Parametric Curve box for output mapping by finding the box whose M parameter matches to <sub>0</sub> . If O <sub>l</sub> is 0, this parameter is ignored.
to <sub>1</sub>	0..15	Selects a nonlinear point output map for component 1 if O <sub>l</sub> is set. Ignored if O <sub>l</sub> is reset.
to <sub>2</sub>	0..15	Selects a nonlinear point output map for component 2 if O <sub>l</sub> is set. Ignored if O <sub>l</sub> is reset.
to <sub>3</sub>	0	Reserved for ITU   ISO/IEC purposes.

Table B.3 — Selection of the output conversion from the parameters

O <sub>c</sub>	C <sub>e</sub>	O <sub>l</sub>	to <sub>i</sub>	Output conversion process
1	1	0	ignored	Half-exponential map for all components specified in <a href="#">Annex D</a>
0	0	0	ignored	Direct output of F <sub>i</sub> , the output the merging process are the reconstructed samples
0	0	1	Selects nonlinear point transformation for component i	The outputs of the merging process F <sub>i</sub> are the input to a nonlinear point transformation selected by to <sub>i</sub> . The value to <sub>i</sub> selects a Floating-Point Table Lookup box or a Parametric Curve box by finding the box whose M value equals the value of to <sub>i</sub>
All other combinations				Reserved for ITU   ISO/IEC purposes.

The nonlinear point transformations selected by this box shall only be Parametric Curve boxes. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range R<sub>w</sub>, R<sub>e</sub> and the output range R<sub>t</sub>, R<sub>f</sub>. The two value pairs shall be given as follows:

$$R_w = 1 \quad R_e = 0$$

$$R_t = 1 \quad R_f = 0$$

The value of the rounding mode *e* shall be 0. Note that for the above choices of R<sub>e</sub> and R<sub>f</sub> the value of the rounding mode parameter *e* is ignored and hence irrelevant.

### B.3 Base Nonlinear Point Transformation Specification box

This box defines the nonlinear point transformation between the output of the Base Transformation and the Colour Transformation. It thus defines step B4 in the decoder description in [Annex A](#). At most, one Base Nonlinear Point Transformation Specification box shall exist as a subbox of the Merging Specification box. It shall not appear at top level of the file. The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B

The nonlinear point transformation selected by this box is an Integer Table Lookup box, a Floating-Point Table Lookup box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subbox of the Merging Specification Box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two value pairs shall be given as follows:

$$R_w = 8 + R_h \quad R_e = 0$$

$$R_t = 8 + R_b \quad R_f = 0$$

The value  $R_h$  is the number of refinement scans in the base decoding path and is found in the Refinement Specification box. If the Refinement Specification box is absent, the inferred value of  $R_h$  is 0.

The value  $R_b$  is found in the Output Conversion box, where  $R_b + 8$  is the output precision of the image.

If this box does not exist, the implied nonlinear point transformation in the base decoding path is defined as if a Parametric Curve box with the identity function, i.e. with parameters  $t = 2$  and  $e = 1$ , had been selected. That is, the input range is linearly scaled to the output range by the parameters  $R_w$  and  $R_t$ .

The type of this box shall be 0x4C52505453, ASCII encoding of "LPTS". The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

#### B.4 Secondary Base Nonlinear Point Transformation Specification box

This box, if present, selects a secondary nonlinear point-transformation that is applied in the precursor image domain **after** the Colour Transformation. This box implements processing step B4a in the description of [Annex A](#), i.e. it maps the linear precursor image sample values  $\Phi_i$  into the final precursor image  $H_i$  to which the prediction residuals  $Q_i$  are added. If this box is not present,  $H_i$  is identical to  $\Phi_i$ . The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B.

The nonlinear point transformation selected by this box is either a Floating-Point Table Lookup Box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two value pairs shall be given as follows:

$$R_w = 8 + R_b \quad R_e = 0$$

$$R_t = 8 + R_b \quad R_f = 0$$

The value  $R_b$  is found in the Output Conversion box, where  $R_b + 8$  is the output precision of the image.

If this box does not exist, the implied nonlinear point transformation in the base decoding path is defined as if a Parametric Curve box with the identity function had been selected, i.e. with parameters  $t = 2$  and  $e = 1$ . That is, the input is identical to the output.

The type of this box shall be 0x43505453, ASCII encoding of "CPTS". The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

#### B.5 Residual Nonlinear Point Transformation Specification box

This box defines the nonlinear point transformation between the output of the residual DCT transformation and the Residual Transformation. It thus defines step B7 in the decoder description in [Annex A](#). At most, one Residual Nonlinear Point Transformation Specification box shall exist as a subbox

of the Merging Specification box. It shall not appear at top level of the file. The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B. This box shall only be present if the Residual Data box is present.

The nonlinear point transformation selected by this box, if it is present, shall be a Parametric Curve box. References to Integer or Floating-Point Table Lookup boxes are not permitted. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two value pairs shall be given as follows:

$$\begin{aligned} R_w &= P + R_r & R_e &= 0 \\ R_t &= 8 + R_b & R_f &= 0 \end{aligned}$$

The value  $R_r$  is the number of residual refinement scans in the base decoding path and is found in the Refinement Specification box. If the Refinement Specification box is absent, the inferred value of  $R_r$  is 0. The value of  $P$  is the bit depth of the residual image; it is found in the frame header of the residual codestream, see Rec. ITU-T T.81 | ISO/IEC 10918-1:1994, Table B.2.

The value  $R_b$  is found in the Output Conversion box, where  $R_b + 8$  is the output precision of the image.

If this box does not exist, the implied nonlinear point transformation in the base decoding path is defined as if a Parametric Curve box with the identity function had been selected, i.e. with parameters  $t = 2$  and  $e = 0$ . That is, the input range is linearly scaled to the output range by the parameters  $R_w$  and  $R_t$ .

The type of this box shall be 0x5152505453, ASCII encoding of "QPTS". The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

NOTE The default rounding mode in the residual domain in the absence of this box is  $e = 0$ , unlike the default rounding mode in the base domain, which is  $e = 1$ . This deviation is intentional.

## B.6 Intermediate Residual Nonlinear Point Transformation Specification box

This box, if present, selects an intermediate nonlinear point-transformation that is applied in the residual domain **after** the Residual Transformation but **before** the Residual Colour Transformation. This box implements processing step B8b in the description of [Annex A](#), i.e. it maps the inversely decorrelated residual error values  $\Psi_i$  into gamma-corrected residual values  $T_i$ . If this box is not present,  $T_i$  is identical to  $\Psi_i$ . The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B.

The nonlinear point transformation selected by this box is either a Floating-Point Table Lookup box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two value pairs shall be given as follows:

$$\begin{aligned} R_w &= 8 + R_b & R_e &= 0 \\ R_t &= 8 + R_b & R_f &= 0 \end{aligned}$$

The value  $R_b$  is found in the Output Conversion box, where  $R_b + 8$  is the output precision of the image.

If this box does not exist, the implied nonlinear point transformation in the residual decoding path is defined as if a Parametric Curve box with the identity function had been selected, i.e. a Parametric Curve box with parameters  $t = 2$  and  $e = 0$ . That is, the input is identical to the output.

The type of this box shall be 0x44505453, ASCII encoding of “DPTS”. The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

### B.7 Secondary Residual Nonlinear Point Transformation Specification box

This box, if present, selects a secondary nonlinear point transformation that is applied in the residual domain **after** the Residual Transformation. This box implements processing step B8d in the description of [Annex A](#), i.e. it maps the inversely decorrelated residual error values  $\Omega_i$  into the final residual error values  $Q_i$  that are added to the precursor image. If this box is not present,  $Q_i$  is identical to  $\Omega_i$ . The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B.

The nonlinear point transformation selected by this box is either a Floating-Point Table Lookup box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two values shall be given as follows:

$$\begin{aligned} R_w &= 8 + R_b & R_e &= 0 \\ R_t &= 8 + R_b & R_f &= 0 \end{aligned}$$

The value  $R_b$  is found in the Output Conversion box, where  $R_b + 8$  is the output precision of the image.

If this box does not exist, the implied nonlinear point transformation in the residual decoding path is defined as if a Parametric Curve box with the identity function had been selected, i.e with parameters  $t = 2$  and  $e = 0$ . That is, the input is identical to the output.

The type of this box shall be 0x52505453, ASCII encoding of “RPTS”. The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

### B.8 Pre-scaling Nonlinear Point Transformation box

This box, if present, computes a point-transformation that computes a pre-scaling factor  $v$  from the luminance of the LDR image, implementing step B3b of [Figure A.1](#). If this box is present, the chroma components  $P_i$  of the residual image are scaled by  $v$ , giving the scaled chroma residuals  $\Pi_i$ . This scaling operation, to be implemented as specified below, implements step B7a of [Figure A.1](#).

If the Pre-scaling Nonlinear Point Transformation box is not present or the residual image consists only of a single component, the inferred value of  $v$  shall be 1, or equivalently, the multiplication of step B7a is skipped.

Scaling of the chroma components, i.e. step B7a of [Figure A.1](#) shall be implemented as follows. It computes the scaled residual components  $\Pi_i$  from the unscaled residual components  $P_i$  according to

$$\begin{aligned} \Pi_0 &= P_0 \\ \Pi_1 &= v \cdot (P_1 - 2^{R_r + P - 1}) + 2^{R_r + P - 1} \\ \Pi_2 &= v \cdot (P_2 - 2^{R_r + P - 1}) + 2^{R_r + P - 1} \end{aligned}$$

where  $R_r$  is the number of refinement scans in the residual image, signalled by the Refinement Specification box and  $P$  is the bit precision signalled in the residual refinement frame header. The luminance component remains unscaled.

If the residual image consists only of a single component, step B7a is skipped and no scaling takes place.

NOTE The above procedure scales the chrominance values around the neutral value by  $v$ .

This box shall never appear top level in the file, but it shall be a subbox of the Merging Specification box defined in ISO/IEC 18477-3:2015, Annex B. At most, one Pre-scaling Nonlinear Point Transformation box shall appear in the Merging Specification box.

The nonlinear point transformation selected by this box is either a Floating-Point Table Lookup box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two value pairs shall be given as follows:

$$\begin{aligned} R_w &= 8 + R_b & R_e &= 0 \\ R_t &= 1 & R_f &= 0 \end{aligned}$$

The type of this box shall be 0x53505453, ASCII encoding of "SPTS". The box structure and layout do not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box, however only parameter  $td_0$  of the box is used.

## B.9 Post-scaling Nonlinear Point Transformation Specification box

This box, if present, selects a point-transformation that computes a post-scaling factor  $\mu$  from the luminance component (component 0) of the residual image. If this box is present, all components  $o$  are multiplied by  $\mu$  after adding the residual image to the precursor image. It hence implements steps B8a and B9 of [Figure A.1](#). If the Post-scaling Nonlinear Point Transformation box is not present, the inferred value of  $\mu$  shall be 1 and scaling of the output components shall be skipped. The box layout of this box is that of the Nonlinear Transformation Specification box, defined in ISO/IEC 18477-3:2015, Annex B.

This box shall never appear top level in the file, but it shall be a subbox of the Merging Specification box defined in ISO/IEC 18477-3:2015, Annex B. At most, one Post-scaling Nonlinear Point Transformation box shall appear in the Merging Specification box.

The nonlinear point transformation selected by this box is either a Floating-Point Lookup box or a Parametric Curve box. The corresponding boxes referenced by this box appear at top level of the ISO/IEC 18477-3 compliant file or as subboxes of the Merging Specification box. The nonlinear point transformation itself is given by the process specified in ISO/IEC 18477-3:2015, Annex C. It requires four additional parameters, the input range  $R_w$ ,  $R_e$  and the output range  $R_t$ ,  $R_f$ . The two values shall be given as follows:

$$\begin{aligned} R_w &= P + R_r & R_e &= 0 \\ R_t &= 1 & R_f &= 0 \end{aligned}$$

where  $P$  is the precision of the residual image frame and  $R_r$  the number of residual refinement scans, taken from the Refinement Specification box.

The type of this box shall be 0x50505453, ASCII encoding of "PPTS". The box structure and layout does not deviate from that in ISO/IEC 18477-3:2015, Annex B, neither apply any restrictions to parameters of the box.

## B.10 Base Transformation box

This box defines the linear transformation between the output of the base entropy decoding process and the input of the base image nonlinear point transformation. It defines the transformation in step B3 of the decoding process specified in [Annex A](#). The box structure and layout is already defined in

ISO/IEC 18477-3:2015, Annex B, though its purpose is refined here. Its definition is intentionally identical to that given in ISO/IEC 18477-6:2016, Annex B.

There shall be, at most, one Base Transformation box as a subbox of the Merging Specification box. This box shall only exist if the number of components  $N_f$  is equal to 3, and it shall exist if the output bit depth is larger than 8, i.e. the  $R_b$  parameter of the Output Conversion box is nonzero.

If the box does not exist, the inverse decorrelation transformation is the identity process if  $N_f$  is equal to 1. If the box does not exist and the number of components is equal to 3, the base transformation in step B3 of Annex A is defined by the Component Decorrelation Control Marker specified in ISO/IEC 18477-1:2015, Annex B, that is, it is the ICT if the Decorrelation Control Marker is absent or its  $cc$  value is equal to 1, it is the identity if the Decorrelation Control Marker exists and its  $cc$  value is 0. Details on the selection of the Base Transformation are specified in ISO/IEC 18477-6:2016, Table C.1.

The linear transformations specified in ISO/IEC 18477-6:2016, Annex C require an additional level shift parameter  $R_s$ . The value of  $R_s$  for the base transformation shall be given as follows:

$$R_s = 8 + R_h - 1$$

where  $R_h$  is the number of refinement scans contained in the base decoding path. The value of  $R_h$  is found in the Refinement Specification box of the Merging Parameter box. It shall be 0 if no Refinement Specification box is present.

The type of the Base Transformation box shall be 0x4C545246, ASCII encoding of "LTRF".

Table B.3 constraints the parameters of the Base Transformation box based on the parameters listed in ISO/IEC 18477-3:2015, Annex B.

**Table B.4 — Parameter constraints for the Base Transformation box**

Parameter	Constraints within this document	Meaning
XT	1, 2 or 5..15	Defines the linear transformation to be used as base transformation, see Table B.6 for the encoding of this field.
Re	0	Shall be 0.

### B.11 Residual Transformation box

This box defines the linear transformation between the output of the nonlinear point transformation in the residual decoding path and the addition of the residual to the output of the Colour Transformation in the base decoding path. It defines the linear transformation in step B8 of the decoding process specified in Annex A. The box structure and layout are already defined in ISO/IEC 18477-3:2015, Annex B, though its purpose is refined here. Its definition is intentionally identical to that given in ISO/IEC 18477-6:2016, Annex B.

This box shall only exist as a subbox of the Merging Specification box specified in ISO/IEC 18477-3:2015, Annex B. It shall not appear top level. This box shall exist, if and only if a Residual Data Box is present at the top level of the file and the number of components  $N_f$  equals 3.

The linear transformations specified in Annex C require an additional level shift parameter  $R_s$ . The value of  $R_s$  for the residual transformation shall be given as follows

$$R_s = 8 + R_b - 1$$

where  $R_b + 8$  is the sample precision of the reconstructed HDR output image. The value of  $R_b$  can be found in the Output Conversion box, see B.2.

The type of this box shall be 0x52545246, ASCII encoding of “RTRF”.

[Table B.5](#) constraints the parameters of the Residual Transformation box from the generic Linear Transformation Specification box defined in ISO/IEC 18477-3.

**Table B.5 — Parameter constraints for the Residual Transformation box**

Parameter	Constraints within this document	Meaning
XT	1, 2 or 5..15	Defines the linear transformation to be used as residual transformation, see <a href="#">Table B.6</a> for the encoding.
Re	0	Shall be 0.

**Table B.6 — Encoding of the XT parameters of the Base and Residual Transformation boxes**

Value	Transformation to be used
0	Reserved for ITU   ISO/IEC purposes.
1	The identity transformation shall be used.
2	The ICT Transformation as specified in ISO/IEC 18477-6:2016, Annex C shall be used.
3	Reserved for ITU   ISO/IEC purposes.
4	Reserved for ITU   ISO/IEC purposes.
5...15	The free-form transformation (with offset shift) defined by the Integer or Floating-Point Linear Transformation box whose M value matches the value of XT shall be used. The Integer or Floating-Point Linear Transformation boxes are specified in ISO/IEC 18477-3:2015, B.2 and B.3 and their application and implementation are specified in ISO/IEC 18477-6:2016, Annex C.

## B.12 Colour Transformation box

This box defines the linear transformation between the output of the nonlinear point transformation in the base domain and the addition of the inversely decorrelated transformed residual. It defines the linear transformation in step B4a of the decoding process specified in [Annex A](#). The box structure and layout are already defined in ISO/IEC 18477-3:2015, Annex B, though its purpose is refined here. The box is intentionally identical to the Colour Transformation box of ISO/IEC 18477-6, its definition is repeated here.

This box shall only exist as a subbox of the Merging Specification box specified in ISO/IEC 18477-3:2015, Annex B and it may only exist if the number of components in the image  $N_f$  equals 3. It shall not appear top level. If this box does not exist, the Colour Transformation shall be the identity transformation; otherwise the XT parameter of the Colour Transformation box specifies the transformation matrix to pick.

The linear transformations specified in ISO/IEC 18477-6:2016, Annex C require an additional level shift parameter  $R_s$ . The value of  $R_s$  for the colour transformation shall be given as

$$R_s = -\infty \text{ (i.e. no level shift)}$$

The type of this box shall be 0x43545246, ASCII encoding of “CTRF”.

[Table B.7](#) constraints the parameters from that defined in ISO/IEC 18477-3.

**Table B.7 — Parameter constraints for the Colour Transformation box**

Parameter	Constraints within this document	Meaning
XT	1 or 5...15	Defines the linear transformation to be used as Base Transformation, see <a href="#">Table B.8</a> for the encoding.
Re	0	Shall be 0.

**Table B.8 — Encoding of the XT parameter of the Colour Transformation box**

Value	Transformation to be used
0	Reserved for ITU   ISO/IEC purposes.
1	The identity transformation shall be used.
2..4	Reserved for ITU   ISO/IEC purposes.
5..15	The free-form transformation (without offset shift) defined by the Integer or Floating-Point Linear Transformation box whose M value matches the value of XT shall be used. The Integer or Floating-Point Linear Transformation boxes are specified in ISO/IEC 18477-3:2015, B.2 and B.3 and their application and implementation are specified in ISO/IEC 18477-6:2016, Annex C.

### B.13 Residual Colour Transformation box

This box defines an additional linear transformation between the output of the nonlinear point transformation in the base domain and the addition of the inversely decorrelated transformed residual. It defines the linear transformation in step B8c of the decoding process specified in [Annex A](#) and computes the values  $\Omega_i$  from the  $T_i$ . If this box is not present, the  $\Omega_i$  shall be identical to  $T_i$ . The box structure and layout are already defined in ISO/IEC 18477-3:2015, Annex B, though its purpose is refined here.

This box shall only exist as a subbox of the Merging Specification box specified in ISO/IEC 18477-3:2015, Annex B and it may only exist if the number of components in the image  $N_f$  equals 3. It shall not appear top level. If this box does not exist, the Residual Colour Transformation shall be the identity transformation; otherwise, the XT parameter of the Residual Colour Transformation box specifies the transformation matrix to pick.

The linear transformations specified in [Annex C](#) require an additional level shift parameter  $R_s$ . The value of  $R_s$  for the residual colour transformation shall be given as

$$R_s = -\infty \text{ (i.e no level shift)}$$

The type of this box shall be 0x44545246, ASCII encoding of “DTRF”.

[Table B.9](#) constraints the parameters of this box from the generic box definition in ISO/IEC 18477-3.

**Table B.9 — Parameter constraints of the Residual Colour Transformation box**

Parameter	Constraints within this Recommendation   International Standard	Meaning
XT	1, 5..15	Defines the linear transformation to be used as Base Transformation, see <a href="#">Table B.10</a> for the encoding.
DRe	0	Shall be 0.

**Table B.10 — Encoding of the XT parameter of the Residual Colour Transformation box**

Value	Transformation to be used
0	Reserved for ITU   ISO/IEC purposes.
1	The identity transformation shall be used.
2..4	Reserved for ITU   ISO/IEC purposes.
5..15	The free-form transformation (without offset shift) defined by the Integer or Floating-Point Linear Transformation box whose M value matches the value of XT shall be used. The Integer or Floating-Point Linear Transformation boxes are specified in ISO/IEC 18477-3:2015, B.5 and B.6 and their application and implementation are specified in ISO/IEC 18477-6:2016, Annex C.

### B.14 Pre-scaling Transformation box

This box defines the linear transformation that computes from the linear precursor image  $\Phi_i$  the luminance. This luminance is mapped by the Pre-scaling Nonlinear Point Transformation box into a pre-scaling factor  $v$  applied to the chroma components of the residual image. It defines the transformation in step B3a of the decoding process specified in [Annex A](#). There shall be, at most, one Base Transformation box as subbox of the Merging Specification box. This box shall exist if and only if the number of components  $N_f$  is equal to 3 and the Pre-scaling Nonlinear Point Transformation Specification box exists. The box structure and layout are already defined in ISO/IEC 18477-3:2015, Annex B, though its purpose is refined here.

If the Pre-scaling Nonlinear Point-Transformation Specification box exists and the number of components  $N_f$  is equal to 1, the input to the pre-scaling nonlinear point transformation is taken from the first (and only) component of the base image. The details of the merging process of residual/refinement data with LDR data are defined in [Annex A](#).

The linear transformations specified in ISO/IEC 18477-6:2016, Annex C require an additional level shift parameter  $R_s$ . The value of  $R_s$  for the pre-scaling transformation shall be given as:

$$R_s = 8 + R_h - 1$$

where  $R_h$  is the number of refinement scans contained in the base decoding path. The value of  $R_h$  is found in the Refinement Specification box of the Merging Parameter box. It shall be 0 if no Refinement Specification box is present.

The type of the Pre-scaling Transformation box shall be 0x53545246, ASCII encoding of "STRF".

[Table B.11](#) constraints the parameters of the Residual Transformation box from the generic Linear Transformation Specification box defined in ISO/IEC 18477-3:2015, Table B specifies the encoding of the XT parameter of the box.

**Table B.11 — Parameter constraints for the Pre-scaling Transformation box**

Parameter	Constraints within this document	Meaning
XT	2, 5..15	Defines the linear transformation to be used as Pre-scaling Transformation, see <a href="#">Table B.12</a> for the encoding.
Re	0	Shall be 0.

**Table B.12 — Encoding of the XT parameter of the Pre-scaling Transformation**

Value	Transformation to be used
0..1	Reserved for ITU ISO/IEC purposes.
2	The forwards ICT Transformation as specified in <a href="#">Annex C</a> shall be used.
3..4	Reserved for ITU ISO/IEC purposes.
5..15	The free-form transformation with offset shift defined by the Integer or Floating-Point Linear Transformation box whose M value matches the value of XT shall be used. The Integer or Floating-Point Linear Transformation boxes are specified in ISO/IEC 18477-3:2015, B.2 and B.3 and their application and implementation are specified in ISO/IEC 18477-6:2016, Annex C.

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## Annex C (normative)

### Multi-component decorrelation

#### C.1 General

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

This annex defines the Multiple Component Decorrelation Transformations available as base, residual and colour transformations of the decoding process. This annex is by itself an extension of ISO/IEC 18477-6:2016, Annex C as it defines one additional transformation that may be selected by the Pre-scaling Transformation box. Additional transforms also applicable in this document are found in ISO/IEC 18477-6:2016, Annex C.

A Multiple Component Decorrelation Transformation takes one or three input components, and generates from them one or three output components. A task dependent level shift by a value of  $2^{R_s}$  ensures that chroma components are correctly centred and representable by unsigned values. The values of  $R_s$  that are applicable to the transformations are specified in [B.10](#) to [B.13](#).

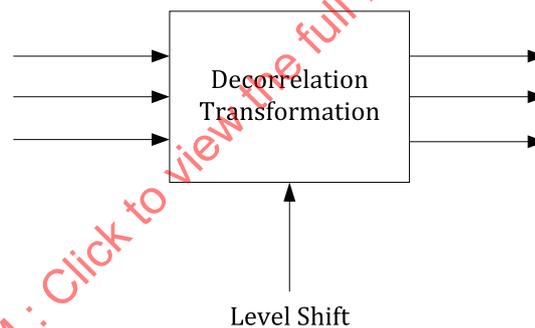


Figure C.1 — Input and output of a decorrelation transformation: Input components, output components and the DC level shift

#### C.2 Irreversible forward multiple component transformation (forward ICT) (normative)

This transformation is used to decorrelate the low dynamic range versions of the image before encoding the components by a Rec. ITU-T T.81 | ISO/IEC 10918-1 conforming encoder. It is identical to the forward ICT defined in ISO/IEC 18477-1. Let  $L_0$  to  $L_2$  be the input pixel values, and  $R_s$  the number of level shift scale bits, then the output  $I_0$  to  $I_2$  shall be computed as

$$\begin{aligned}
 I_0 &= 2,990\ 0 \cdot L_0 & + & 0,587\ 00 \cdot L_1 & + & 0,114\ 00 \cdot L_2 \\
 I_1 &= -0,168\ 7358916 \cdot L_0 & - & 0,331\ 2641084 \cdot L_1 & + & 0,5 \cdot L_2 & + & 2^{R_s} \\
 I_2 &= 0,5 L_2 & - & 0,418\ 6875892 \cdot L_1 & - & 0,081\ 31241085 \cdot L_2 & + & 2^{R_s}
 \end{aligned}$$

NOTE This transformation is intentionally identical to the forward ICT in ISO/IEC 18477-6. However, while only informative in ISO/IEC 18477-6, it is normative here. Note further that outputs  $I_1$  and  $I_2$  are not required for processing the Pre-scaling Transformation and their computation may be skipped.

## Annex D (normative)

### Half-exponential output transformation

#### D.1 General

In this annex and all of its subclauses, the flow charts and tables are normative only in the sense that they are defining an output that alternative implementations shall duplicate.

This annex defines an output conversion that transforms integer sample values to floating-point values. It is selected as the final step for generating output sample values from the sum of base and residual image. This type of output conversion is applied whenever the Oc flag of the Output Conversion box specified in [B.2](#) is set to 1.

If this output conversion is set, the (potential) floating-point output of the merging step is rounded to the nearest integer, and then clamped to the range  $[-0x7bff, 0x7bff]$ . This integer is then converted to floating-point by the procedure specified in [D.2](#).

#### D.2 Half-exponential output conversion

This annex defines an optional output transformation denoted by  $\Psi_{\text{exp}}$  that may help to improve the compression performance for floating-point sample values. This output transformation is effective whenever the Oc parameter of the Output Conversion box is 1, see [B.2](#) for details on this box. The  $\Psi_{\text{exp}}$  map implements a half-exponential map that converts its integer input to a floating-point output.

The  $\Psi_{\text{exp}}$  map is defined for non-negative inputs ( $x \geq 0$ ) by the following steps.

- The integer input  $x$  shall be represented in a 16-bit binary representation.
- The resulting bit-pattern shall be re-interpreted as an ISO/IEC IEEE 60559 (IEEE 754) floating-point number. This floating-point number is the final output of the output transformation.

For negative inputs ( $x < 0$ ), the output of  $\Psi_{\text{exp}}$  is defined as  $\Psi_{\text{exp}}(x) = -\Psi_{\text{exp}}(-x-1)$ .

NOTE It can be seen that this re-interpretation of bit-patterns on non-negative integers is equivalent to a piecewise linear approximation of the exponential function  $f(x)$  approximately  $(2^{y-15})$  with  $y = x \cdot 2^{-10}$ . The definition for negative numbers ensures that  $\Psi_{\text{exp}}(-1)$  maps to the binary representation of the floating-point number  $-0$ .

## Annex E (normative)

### Profiles

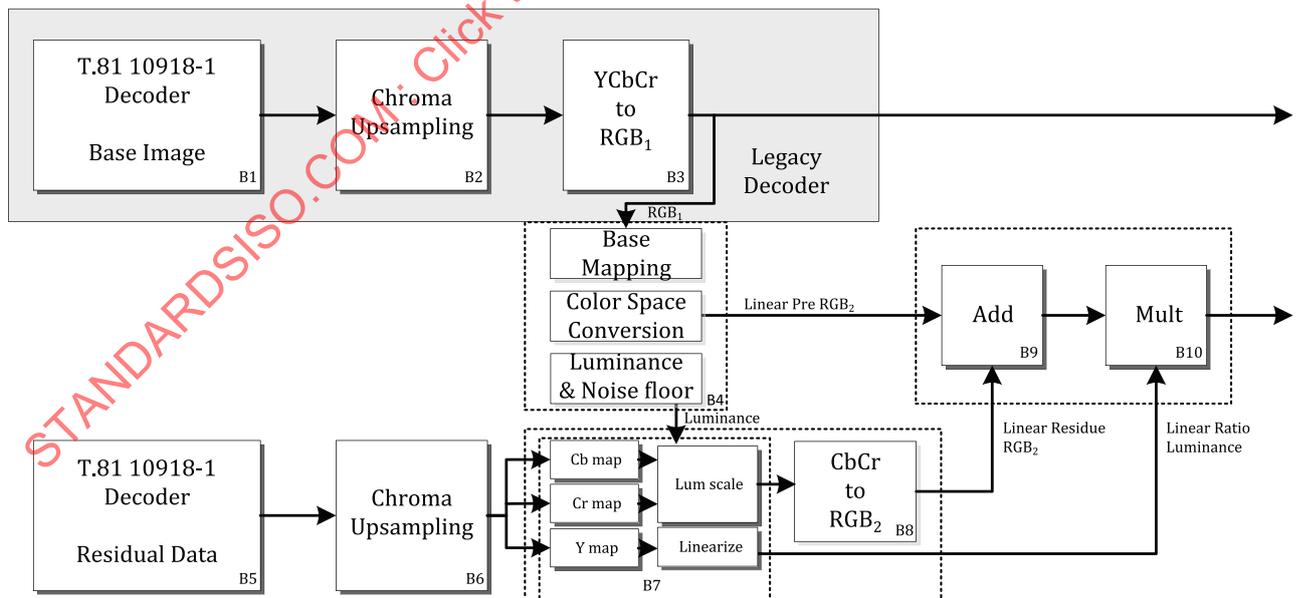
#### E.1 General

This annex defines four profiles that limit the choices of coding parameters offered by this document. Profile A implements a decoding algorithm that is identical to the decoding algorithm specified in ISO/IEC 18477-2. Profile B specifies a decoding algorithm that computes the HDR output image as the quotient of the base image and the residual image. Profile C defines a simple additive profile that is compatible to the lossless HDR image coding specified in ISO/IEC 18477-8 and allows scalable lossy to lossless coding. Profile D implements a minimal HDR decoder that does not require a residual codestream. Coding performance of the profiles may differ, and will also depend on the input image.

Profiles are indicated by an additional entry in the Compatibility List of the File Type box, specified in ISO/IEC 18477-3:2015, Annex B. A decoder claiming performance to one of the profiles does not need to implement any mechanism that is not included in the profile, and it may use an optimized decoding procedure that bypasses some of the intermediate results specified in [Annex A](#) provided that its final output is equivalent to that of the hypothetical reference decoder.

#### E.2 Profile A

[Figure E.1](#) gives a high-level overview of this profile. It is, with appropriate choices of parameters, a specialization of the decoding procedure described in [Annex A](#). The profile indicator of this profile, i.e. the entry  $CL_i$  in the compatibility list of the File Type box shall be 0x78726464, ASCII encoding for “xrdd”.



**Figure E.1 — High-level overview of the decoding process of a Profile A compliant decoder**

The following constraints apply to a Profile A compliant decoder.

- The residual image bit precision  $P$  shall be constrained to 8.

- The Refinement Specification box (see ISO/IEC 18477-6:2016, Annex D) shall be absent. This implies that no refinement scans are present and no Refinement Data or Residual Refinement boxes are present.
- The XT value of the Base Transformation box shall be 2. That is, the base transformation shall be the ICT.
- The Base Nonlinear Point Transformation box shall select identical transformations for all components. Specifically, the transformation shall be defined by either a Parametric Curve box with a curve type  $t = 4$  (gamma mapping) or a Floating-Point Table Lookup box. If the Parametric Curve box is selected, it is constrained to the following parameters:

$$e = 1 \qquad P_1 = 0,040\ 45 \qquad P_2 = 2,4 \qquad P_3 = 0,055$$

This selects the IEC 61966-2 (sRGB) nonlinearity and maps sRGB gamma corrected samples into a linear gamma space.

NOTE The entries of the Floating-Point Lookup Table box have to be rescaled compared to the entries found in the bga tag of ISO/IEC 18477-2. The former has a nominal range of [0,653 55] while the latter has a range of [0,1]. Thus, entries of the bga tag have to be multiplied by 655 35 before using them as entries in the Floating-Point Table Lookup Table box referenced by the Base Nonlinear Point Transformation box.

No secondary base transformation box shall be present.

- The Colour Transformation box shall be either absent, or shall have an XT value of 1 or larger than 4, i.e. select either the identity transformation or a free-form transformation. The free-form transformation shall point to a Floating-Point Linear Transformation box.
- The Pre-scaling Transformation box shall be present if and only if the number of components is 3.
- The Pre-scaling Nonlinear Point Transformation boxes shall be present and shall select a Parametric Curve box of curve type  $t = 5$  (linear ramp). Parameters shall be selected as follows:

$$e = 1 \qquad P_1 = \text{noise floor value} \qquad P_2 = \text{noise floor value} + 1$$

This choice of parameters ensures that the pre-scaling value  $v$  is computed as  $v = L + NF$ , where  $L$  is the luminance of the base image and  $NF$  is the noise floor value specified in ISO/IEC 18477-2.  $R_w$  is here always 16.

- The Residual Nonlinear Point Transformation Specification box shall refer to Parametric Curve boxes with box types  $t = 5$  (linear ramp). The parameters shall be selected as follows:

$e = 0$	$P_1 = P_2 = \frac{1}{2}$	for component 0 (residual luminance)
$e = 1$	$P_1 = cb0 + \frac{1}{2}$ $P_2 = cb1 + \frac{1}{2}$	for component 1 (blue-yellow)
$e = 1$	$P_1 = cr0 + \frac{1}{2}$ $P_2 = cr1 + \frac{1}{2}$	for component 2 (red-green)

This choice of parameters implements the same scaling as in ISO/IEC 18477-2 and adds a relative offset of  $2^{R_t-1}$ . This offset is then again subtracted by the Residual Transformation chroma offset. The choice  $P_1 = P_2 = \frac{1}{2}$  for component 0 creates an offset shift of  $2^{R_b+8-1}$  in the output that is compensated by offset included when merging the residual and base image as indicated in [Annex A](#). According to [Annex B](#),  $R_w = 8$  and  $R_t = 16$ .

- The Residual Transformation box shall exist if and only if  $N_f = 3$ . It shall signal an XT value of 2 or larger than 4, selecting either the ICT or a free-form decorrelation transformation.
- The Intermediate Residual Nonlinear Point Transformation box and the Residual Colour Transformation box shall not be present.

- The Post-scaling Nonlinear Transformation box shall be present and shall either point to a Parametric Curve box of curve type  $t = 6$  (exponential) or to a Floating-Point Lookup box. In the former case, parameters shall be selected as follows:

$$e = 1 \quad P_1 = \ln 0 \cdot \log(2) \quad P_2 = \ln 1 \cdot \log(2) \quad P_3 = 1 \quad P_4 = 0$$

This choice of parameters scales the residual luma value according to the exponential map as in ISO/IEC 18477-2. According to [Annex B](#),  $R_w = 8$  in the above formula.

- The Secondary Base Nonlinear Point Transformation box shall not be present and inversely decorrelated prediction errors  $\Omega_i$  are identical to the final error residuals  $Q_i$ .
- The Secondary Residual Nonlinear Point Transformation box shall not be present and inversely decorrelated prediction errors  $\Omega_i$  are identical to the final error residuals  $Q_i$ .
- The Output Conversion box shall have the flag values  $O_l = 1$ ,  $O_c = 0$  and  $C_e = 0$  indicating that an output conversion is active. The  $to_i$  values of the Output Conversion box shall point to three identical or one Parametric Curve box of curve type  $t = 5$ . This Parametric Curve box shall contain the following parameters:

$$e = 1 \quad P_1 = 0 \quad P_2 = 1/(2^{8+R_b}-1)$$

This choice of the output conversion scales the output from the nominal range of  $2^{R_b+8}$  to a unit range.

Suggestions on how to compute the parameters from an LDR, HDR image pair instead of the parameters from ISO/IEC 18477-2 can be found in [Annex F](#).

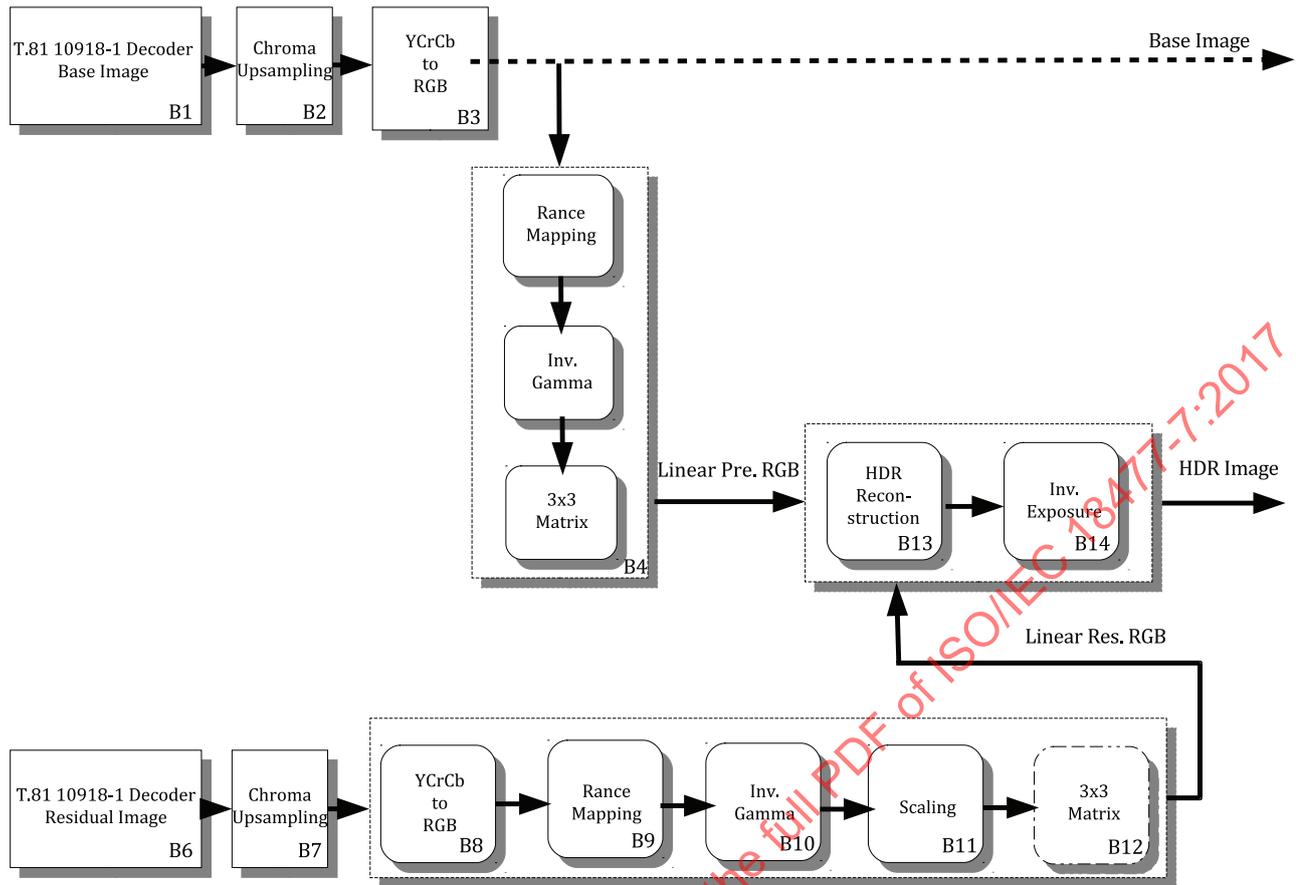
### E.3 Profile B

Profile B implements a simpler HDR decoding process than Profile A requiring less scaling steps. [Figure E.2](#) gives a high-level overview on this profile. The profile indicator of this profile, i.e. the entry  $CL_i$  in the compatibility list of the File Type box, shall be 0x78727864, ASCII encoding for "xrxd".

Profile B decomposes an HDR image into a base layer and an HDR residual layer. The LDR input image has to be represented in a linear space (no gamma correction) or should be linearized at encoding level. That is, sample values have to have sample values proportional to physical luminance. The base is either an exposed and clamped or a tone mapped version of the original floating-point HDR image. This codestream will be the backwards compatible part and will be accessible by all legacy decoders. The residual image contains the fractional part of the tone mapped LDR image divided by the original HDR image carried out channel by channel in RGB space, and converted to YCrCb. The residual data are also encoded with an Rec. ITU-T T.81 | ISO/IEC 10918-1 encoder using only the baseline or extended Huffman or progressive 8 bit modes, and the Number of Components signalled in the residual frame header shall be identical to the number of components in the base image.

JPEG XT compliant decoders will combine the two as described below to recover the HDR image. The details of this merging process are outlined below.

[Figure E.2](#) illustrates the functionality of a Profile B decoder.



**Figure E.2 — High-level overview of the decoding process of a Profile B compliant decoder**

The following constraints apply to a Profile B compliant decoder.

- The residual image bit precision  $P$  shall be constrained to 8.
- The number of components of the residual image in the Residual Code Stream box shall be identical to the number of components in the legacy codestream.
- The Refinement Specification box (see ISO/IEC 18477-3:2015, Annex D) shall be absent. This implies that no refinement scans are present and no Refinement Data or Residual Refinement boxes are present.
- All Parametric Curve boxes and Floating-Point Transformation boxes shall appear as subboxes of the Merging Specification boxes. Parametric Curve boxes and Floating-Point Transformation boxes shall not appear at top level of the file.
- The Pre-scaling Nonlinear Point Transformation box and the Post-scaling Nonlinear Point Transformation box shall be absent. That is, the pre-scaling factor  $v$  and the post-scaling factor  $\mu$  shall both be 1.
- The XT value of the Base Transformation box shall be either 2 or larger than 4. That is, the base transformation shall either be the ICT or a free-form transformation.
- The Base Nonlinear Point transformation box shall point to a single Floating-Point Lookup box or three identical or a single Parametric curve box selecting a curve type of  $t = 4$ . Parameters for the Parametric Curve box are constrained as follows:

$$\begin{array}{llll}
 e = 1 & P_1 = P_3 = 0 & P_2 = \text{ldr\_gamma}, & \text{or} \\
 e = 1 & P_1 = 0,040\ 45 & P_2 = 2.4 & P_3 = 0,055
 \end{array}$$

This selects an inverse gamma correction without knee value or sRGB nonlinearity.

- The Colour Transformation box shall either be absent or specify a free-form transformation. The free-form transformation shall be defined by a Floating-Point Linear Transformation box.
- The Secondary Base Nonlinear Point Transformation box shall point to three identical or one Parametric Curve box selecting a parametric curve of curve type  $t = 7$ . The parameters of this map shall be as follows:

$$e = 1 \quad P_1 = 1 \quad P_2 = 1 \quad P_3 = \varepsilon \quad P_4 = 0$$

This selects a logarithmic map. Parameter  $P_3$  adds a small offset that avoids taking the logarithm of zero. A suggested value of  $\varepsilon$  is  $10^{-7}$ .

- The Residual Nonlinear Point Transformation box shall be absent.
- The Residual Transformation box shall either select a free-form transformation or have an XT value of 1 indicating the ICT.
- The Intermediate Residual Transformation box shall point to one or three Parametric Curve boxes of type  $t = 8$ . The parameter shall be constraint as follows.

$$e = 1 \quad P_1 = \min \quad P_2 = \max \quad P_3 = \text{hdr\_gamma}$$

This selection of parameters first applies an inverse gamma correction of the residual image with the exponent *HDR\_gamma* and then scales the output, including the output scaling of ISO/IEC 18477-3:2015, Annex C, to the range  $[\min \cdot (2^{Rb+8} - 1), \max \cdot (2^{Rb+8} - 1)]$ . If the parameters differ between components, three boxes need to be written; otherwise, a single box is sufficient which is used by all components consistently.

- The Residual Colour Transformation box shall be present if and only if the Colour Transformation box is present. If it is present, its DXt parameter shall be identical to the DXt parameter of the Colour Transformation box, i.e. both boxes shall refer to the same Floating-Point Linear Transformation box.
- The Secondary Residual Nonlinear Point Transformation box shall point to three identical or one Parametric Curve box selecting a parametric curve of curve type  $t = 7$ . The parameters of this map shall be as follows:

$$e = 1 \quad P_1 = -1,0 \quad P_2 = 1,0 \quad P_3 = \varepsilon \quad P_4 = 32768/65535$$

The negative sign of  $P_1$  computes the negative logarithm instead of the positive logarithm.  $P_1$  then scales the output of the Residual Transformation box to  $[0,1]$ .  $P_3$  avoids a pole by normalizing the output, a suggested value for  $\varepsilon$  is  $10^{-7}$ .  $P_4$  corrects for the subtraction of the neutral value  $2^{8+Rb-1}$  present in step B9 of the decoding procedure described in [Annex A](#).

- The Output Conversion box shall signal the flag values  $O_c = 0$   $C_e = 0$   $O_l = 1$ . This enables the selection of an output nonlinearity. The  $to_i$  values of the Output Conversion box shall point to three identical or one Parametric Curve box of curve type  $t = 6$ . This Parametric Curve box shall contain the following parameters:

$$e = 1 \quad P_1 = 0 \quad P_2 = 1/(2^{Rb+8}-1) \quad P_3 = \text{exposure-value} \quad P_4 = 0$$

The exposure value denotes here the choice of an exposure for the reconstructed image.

NOTE The parameter constraints of the Secondary Base, Intermediate and Residual Nonlinear Point Transformation box and the selection of the output conversion enforce that the merging process between the LDR base image and the residual image is given by the following formula:

$$\begin{aligned} & \text{expval} \cdot \exp\left(\mu \cdot \left(H_i + Q_i - 2^{Rb+8-1}\right)\right) \\ &= \text{expval} \cdot \exp\left(\log\left(\Phi_i / \left(2^{Rb+8} - 1\right)\right) - \log\left(\left(\Omega_i / \left(2^{Rb+8} - 1\right)\right) + \varepsilon\right) + 2^{Rb+8-1} - 2^{Rb+8-1}\right) \\ &= \text{expval} \cdot \varphi_i / (\omega_i + \varepsilon) \end{aligned}$$

with  $\omega_i = \Omega_i / (2^{Rb+8-1})$  the residual and  $\varphi_i = \Phi_i / (2^{Rb+8-1})$  the base image sample values scaled to [0,1]. The value of  $\mu$  here is always 1 due to the absence of the post-scaling transformation.

A decoder conforming to Profile B does not need to implement the logarithmic and exponential map of the Secondary Base and Residual Nonlinear Point Transformation and the Output Transformation, but may instead apply the right hand side of the above formula directly without going through all the intermediate steps. This will not only lower the algorithmic complexity, but also improve the accuracy of the algorithm. Furthermore, note that the output of the Secondary Base/Residual Nonlinear Point Transformation box is scaled by the algorithm specified in ISO/IEC 18477-3:2015, Annex C by a factor of  $2^{Rb+8} - 1$  which is again removed by the input scaling of the Output Conversion box. That is, practical implementations may want to skip the output scaling of the Secondary Nonlinear Transformations and the input scaling of the Output Conversion box. Output scaling by the algorithm of Annex C in the Output Conversion box is also un-done by the choice of  $P_3$  of the Parametric Curve box referenced by the Output Conversion box.

With these simplifications in place, decoding consists of the following steps.

- Scale the output of the LDR reconstruction process  $O_i$  from step B3 to the range [0,1] according to ISO/IEC 18477-3:2015, Annex C. In Figure E.2, this step is performed in step B4.
- Perform the pointwise nonlinearity transformation in step B4. This is part of the nonlinear point transformation; the outputs are the predicted high dynamic range sample values  $J_i$ . In profile B, the nonlinearity is either given by a lookup table, a sRGB-type of nonlinearity or a power law with the exponent taken from parameter  $P_2$  of the Parametric Curve box pointed to by Base Nonlinear Point Transformation box.
- Since the chroma scaling factor  $v$  is always 1 in profile B and the Residual Nonlinear Point Transformation is always the identity, the values  $\Pi_i$  are identical to the reconstructed residual sample values  $P_i$  scaled to the range  $[0, 2^{Rb-1}]$ .
- In step B8, a YCbCr to RGB transformation (ICT) is applied to the reconstructed residual data  $P_i$  by applying a  $3 \times 3$  matrix transformation and a level shift, generating the output  $\Psi_i$ . Due to the absence of pre-scaling, the factor  $v$  is 1 and  $\Pi_i$  equals  $P_i$ .
- Step B9 scales the values  $\Psi_i$  input to [0,1]. This step is implicit in the input and output scaling of the **Secondary Residual Nonlinear Point Transformation** and **Intermediate Residual Nonlinear Point Transformation**, and is specified in ISO/IEC 18477-3:2015, Annex C.
- In step B10, an inverse gamma correction is applied to the residual sample values  $\Psi_i$  giving the gamma-corrected decorrelated samples  $T_i$ . This operation is implemented by the **Intermediate Nonlinear Point Transformation**. The exponent comes from the  $P_3$  value of the Parametric Curve box pointed to by the Intermediate Nonlinear Point Transformation Specification box, the output scaling from the parameter  $P_1$  and  $P_2$ . The exponent is signalled as value  $P_3$  in the Parametric Curve box referenced by the Intermediate Nonlinear Point Transformation box.
- In step B11, the output of the inverse gamma mapping is scaled to the range [min, max] by multiplying the gamma-corrected values with (*min-max*) and adding an offset shift *min*. The operation is performed along with the inverse gamma correction in step B10 by the Parametric Curve box. The parameters *min* and *max* are signalled as parameters  $P_1$  and  $P_2$  of the Parametric Curve box signalled by the Intermediate Nonlinear Point Transformation box. Note that each component may refer to a different Parametric Curve box, thus exponent values and min/max values may differ between components.