BS ISO/IEC 18477-7:2016

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

Part 7: HDR Floating-Point Coding

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National foreword

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The UK participation in its preparation was entrusted to Technical Committee IST/37, Coding of picture, audio, multimedia and hypermedia information.

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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.

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The committee responsible for this document is ISO/IEC JTC 1, *Information technology*, SC 29, *Coding of audio, picture, multimedia and hypermedia information*.

ISO/IEC 18477 contains the following parts under the general title *Information technology — Scalable compression and coding of continuous-tone still images*:

— *Part 1: Scalable compression and coding of continuous-tone still images*

— *Part 2: Extensions for high dynamic range images*

— *Part 3: Box file format*

— *Part 6: IDR Integer Coding*

— *Part 7: HDR Floating-Point Coding*

— *Part 8: Lossless and Near-lossless Coding*

— *Part 9: Alpha Channel Coding*

The following parts are to be published:

— *Part 4: Conformance testing*

— *Part 5: Reference software*

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Introduction

This part of ISO/IEC 18477 specifies a coded codestream format for storage of continuous-tone high and low dynamic range photographic content. JPEG XT part 6 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 encoder side by tonemapping from the high dynamic image; while the LDR image is always present, this part of ISO/IEC 18477 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 8 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 colourspace.

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 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 part of ISO/IEC 18477.

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 part of ISO/IEC 18477 is an extension of ISO 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 part of ISO/IEC 18477, though will possibly not be able to reconstruct such streams in full dynamic range, full quality or other features defined in this part of ISO/IEC 18477.

This part of ISO/IEC 18477 is itself based on ISO/IEC 18477-3 which defines a box-based file format similar to other JPEG standards. The aim of this part of ISO/IEC 18477 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 part of ISO/IEC 18477 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 part of ISO/IEC 18477 specifies a coding format, referred to as JPEG XT, which is designed primarily for continuous-tone photographic content.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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: Extensions for high dynamic range images*

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

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

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.

3.1.1
ASCII encoding
encoding of text characters and text strings according to ISO/IEC 10646

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

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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

3.1.4
binary decision
choice between two alternatives

3.1.5
bitstream
partially encoded or decoded sequence of bits comprising an entropy-coded segment

3.1.6
block
8 × 8 array of samples or an 8 × 8 array of DCT coefficient values of one component

3.1.7
box
structured collection of data describing the image or the image decoding process embedded into one or multiple APP_{11} marker segments

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

3.1.8
byte
group of 8 bits

3.1.9
coder
embodiment of a coding process

3.1.10
coding
encoding or decoding

3.1.11
coding model
procedure used to convert input data into symbols to be coded

3.1.12
(coding) process
general term for referring to an encoding process, a decoding process, or both

3.1.13
compression
reduction in the number of bits used to represent source image data

3.1.14
component
two-dimensional array of samples having the same designation in the output or display device

Note 1 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

3.1.16
data unit
8 × 8 block of samples of one component in DCT-based processes; a sample in lossless processes

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3.1.17
decoder
embodiment of a decoding process

3.1.18
decoding process
process which takes as its input compressed image data and outputs a continuous-tone image

3.1.19
dequantization
inverse procedure to quantization by which the decoder recovers a representation of the DCT coefficients

3.1.20
discrete cosine transform
DCT
either the forward discrete cosine transform or the inverse discrete cosine transform

3.1.21
downsampling
procedure by which the spatial resolution of a component is reduced

3.1.22
encoder
embodiment of an encoding process

3.1.23
encoding process
process which takes as its input a continuous-tone image and outputs compressed image data

3.1.24
entropy-coded (data) segment
independently decodable sequence of entropy encoded bytes of compressed image data

3.1.25
entropy decoder
embodiment of an entropy decoding procedure

3.1.26
entropy decoding
lossless procedure which recovers the sequence of symbols from the sequence of bits produced by the entropy encoder

3.1.27
entropy encoder
embodiment of an entropy encoding procedure

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

3.1.29
grayscale image
continuous-tone image that has only one component

3.1.30
high dynamic range
image or image data comprised of samples using a floating point representation

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3.1.31
Huffman decoder
embodiment of a Huffman decoding procedure

3.1.32
Huffman decoding
entropy decoding procedure which recovers the symbol from each variable length code produced by the Huffman encoder

3.1.33
Huffman encoder
embodiment of a Huffman encoding procedure

3.1.34
Huffman encoding
entropy encoding procedure which assigns a variable length code to each input symbol

3.1.35
joint photographic experts group
JPEG
informal name of the committee which created this International Standard

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

3.1.36
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, i.e. the legacy codestream consists of the collection of all markers except those APP_{11} markers that describe JPEG XT boxes by the syntax defined in Annex A

3.1.37
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

3.1.38
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)

3.1.39
lossless coding
mode of operation which refers to any one of the coding processes defined in this part of ISO/IEC 18477 in which all of the procedures are lossless

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

3.1.40
lossy
descriptive term for encoding and decoding processes which are not lossless

3.1.41
low dynamic range
image or image data comprised of data with no more than eight bits per sample

3.1.42
marker
two-byte code in which the first byte is hexadecimal FF and the second byte is a value between 1 and hexadecimal FE

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3.1.43
marker segment
marker together with its associated set of parameters

3.1.44
pixel
collection of sample values in the spatial image domain having all the same sample coordinates, e.g. a pixel may consist of three samples describing its red, green and blue value

3.1.45
precision
number of bits allocated to a particular sample or DCT coefficient

3.1.46
procedure
set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

3.1.47
quantization value
integer value used in the quantization procedure

3.1.48
quantize
act of performing the quantization procedure for a DCT coefficient

3.1.49
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

3.1.50
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

3.1.51
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

3.1.52
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

3.1.53
sample
one element in the two-dimensional image array which comprises a component

3.1.54
sample grid
common coordinate system for all samples of an image

Note 1 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.

3.1.55
scan
single pass through the data for one or more of the components in an image

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3.1.56
scan header
marker segment that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a scan

3.1.57
table specification data
coded representation from which the tables used in the encoder and decoder are generated and their destinations specified

3.1.58
(uniform) quantization
procedure by which DCT coefficients are linearly scaled in order to achieve compression

3.1.59
upsampling
procedure by which the spatial resolution of a component is increased

3.1.60
vertical sampling 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

3.1.61
zero byte
0x00 byte

3.1.62
zig-zag sequence
specific sequential ordering of the DCT coefficients from (approximately) lowest spatial frequency to highest

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 invers 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

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3.3 Abbreviations

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 part of ISO/IEC 18477 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 part of ISO/IEC 18477 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 part of ISO/IEC 18477 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 part of ISO/IEC 18477.

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 part of ISO/IEC 18477 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

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4.2.2 Logical operators

|| Logical OR

&& Logical AND

! Logical NOT

∈ x ∈ {A, B} is defined as (x == A || x == B)

∉ x ∉ {A, B} is defined as (x != A && x != 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
sign(x)	Sign of x, 0 if x is zero, +1 if x is positive, -1 if x is negative.
clamp(x, min, max)	Clamps x to the range [min, max]: returns min if x < min, max if x > max or otherwise x.

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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 × 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

The purpose of this Clause is to give an informative overview of the elements specified in this part of ISO/IEC 18477. 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 part of ISO/IEC 18477.

a) 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*.

b) 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*.

c) 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.

5.1 High level overview on JPEG XT ISO 18477-7 (informative)

This part of ISO/IEC 18477 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 part of ISO/IEC 18477 correctly, albeit only in 8-bit sample precision with a limited dynamic range and potentially a limited colour gamut.

This part of ISO/IEC 18477 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 part of ISO/IEC 18477 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

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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 colourspace. Optionally, the luma signal of the LDR image is computed from the BT.601 colourspace and used as **prescaling** of the chroma signals of the residual. The BT.601 image is optionally transformed again into a wider colourspace. For practical reasons, the transformations from YCbCr to BT.601 and from BT.601 into an output colourspace 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 colourspace 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 prescaling 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 colourspace into the target colourspace. 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 convers 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.

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