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

Part 4: Conformance testing

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

Partie 4: Essai de conformité

Reference number
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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 ISO documents 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).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO 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).

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.

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

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

Introduction

The ISO/IEC 18477 series, also known under the term JPEG XT, specifies lossy and lossless codestream formats for storage of continous-tone high and low dynamic range photographic content. All parts of the ISO/IEC 18477 series are compatible to the Recommendation ITU-T T.81 | ISO/IEC 10918, also commonly known as JPEG. That is, any decoder conforming to the latter standard will be able to reconstruct codestreams from the ISO/IEC 18477 series to an 8 bits/sample image. Additional features offered by ISO/IEC 18477, such as representation of intermediate or high-dynamic range images, or lossless reconstruction require an extended decoder that implements, in addition to the Rec. ITU-T T.81 | ISO/IEC 10918-1, also one or multiple members of ISO/IEC 18477.

This document provides the framework, concepts and methodology for testing codestreams and implementations, and the criteria to be achieved to claim conformance to the parts and profiles of ISO/IEC 18477. The objective of this document is to promote interoperability between JPEG XT decoders, and to test these systems for conformance to one or multiple specifications that are part of the JPEG XT. Conformance testing is the testing of a candidate implementation for the existence of specific characteristics required by a standard. It involves testing the capabilities of an implementation against the conformance requirements in the relevant standard.

The purpose of this document is to define a common test methodology, to provide a framework for specific abstract test suites (ATS) and to define the procedures to be followed during conformance testing.

Any organization contemplating the use of the test methods defined in this document should carefully consider the constraints on their applicability. Conformance testing does not include robustness testing, acceptance testing, and performance testing, all of which are outside the scope of this text.

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

Part 4: Conformance testing

1 Scope

This document specifies the framework, concepts, methodology for testing, and criteria to be achieved to claim conformance to one or multiple parts of ISO/IEC 18477 as listed below. It provides a framework for specifying abstract test suites and for defining the procedures to be followed during conformance testing.

This document

- specifies conformance testing procedures for decoding of ISO/IEC 18477-1, 18477-2, ISO/IEC 18477-6, ISO/IEC 18477-7, ISO/IEC 18477-8 and ISO/IEC 18477-9,
- specifies conformance testing procedures for codestreams to the above International Standards,
- specifies codestreams, decoded images, and error metrics to be used within the decoder testing procedures, and
- specifies abstract test suites.

This document does not include the following tests:

- testing **decoders** for conformance to ISO/IEC 18477-3 only. ISO/IEC 18477-6, ISO/IEC 18477-7, ISO/IEC 18477-8 and ISO/IEC 18477-9 are extensions of ISO/IEC 18477-3 and the required functionality of ISO/IEC 18477-3 is tested as part of the former standards. Testing **codestreams** for conformance to ISO/IEC 18477-3 is specified in C.2;
- testing codestreams for conformance to ISO/IEC 18477-7 beyond testing them for conformance to individual profiles of this document. Testing such codestreams ("full profile codestreams") for syntactical correctness is, however, covered by testing them for conformance to ISO/IEC 18477-3;
- testing of the composition of background and foreground for images reconstructed from ISO/IEC 18477-9 codestreams as this operation is application dependent;
- acceptance testing: the process of determining whether an implementation satisfies acceptance criteria and enables the user to determine whether or not to accept the implementation. This includes the planning and execution of several kinds of tests (e.g. functionality, quality, and speed performance testing) that demonstrate that the implementation satisfies the user requirements;
- performance testing: measures the performance characteristics of an implementation under test (IUT) such as its throughput, responsiveness, etc. under various conditions.
- robustness testing: the process of determining how well an implementation process data which contains errors.

The ISO/IEC 18477 series consists of multiple parts, each of which defines one or multiple profiles. A given IUT (implementation under test) may claim to implement various parts and profiles of ISO/IEC 18477 at once. To test such implementations, they have to be tested with the Abstract Test Suites of each part and profile they claim to conform to.

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

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

ISO/IEC 18477-7, *Information technology: Scalable compression and coding of continuous-tone still images, HDR floating point coding*

ISO/IEC 18477-8, *Information technology — Scalable compression and coding of continuous-tone still images — Part 8: Lossless and near-lossless coding*

ISO/IEC 18477-9, *Information technology — Scalable compression and coding of continuous-tone still images — Part 9: Alpha channel coding*

ISO/IEC 10918-1, *Information technology — Digital compression and coding of continuous tone still images — Requirements and guidelines*

3 Terms, definitions, abbreviated terms and symbols

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 Terms and definitions

3.1.1
abstract test suite
generic conformance testing concepts and procedures for a given requirement

3.1.2
ASCII
binary encoding of 7-bit characters defined by ISO/IEC 646

3.1.3
base decoding path
process of decoding *legacy codestream* (3.1.43) and refinement data to the *base image* (3.1.4), jointly with all further steps until residual data is added to the values obtained from the residual codestream

3.1.4
base image
collection of sample values obtained by entropy decoding the DCT coefficients of the *legacy codestream* (3.1.43) and the refinement codestream, and inversely DCT transforming them jointly

3.1.5
big endian
order of bytes with the most significant byte first

3.1.6
bit
unit of information representing a single yes/no choice represented by a one or a zero

3.1.7
binary decision
choice between two alternatives

3.1.8
bitstream
partially encoded or decoded sequence of *bits* (3.1.6) comprising an entropy-coded segment

3.1.9
block
8 × 8 array of *samples* (3.1.62) or an 8 × 8 array of DCT coefficient values of one *component* (3.1.19)

3.1.10
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 the definition of boxes.

3.1.11
byte
group of 8 bits

3.1.12
coder
embodiment of a *coding process* (3.1.14)

3.1.13
coding model
procedure used to convert input data into symbols to be coded

3.1.14
coding process
general term for referring to an encoding process, a decoding process, or both

3.1.15
coefficient
values that are the result of a discrete cosine transformation

3.1.16
conformance
fulfillment of the specified requirements, as defined in this document, for a given profile and part of ISO/IEC 18477

3.1.17
conformance test procedure
process of assessing *conformance* (3.1.16)

3.1.18
compression
reduction in the number of *bits* (3.1.6) used to represent source image data

3.1.19
component
two-dimensional array of *samples* (3.1.62) having the same designation in the output or display device

3.1.20
continuous-tone image
image whose *components* (3.1.19) have more than one *bit* (3.1.6) per *sample* (3.1.62)

3.1.21
decoder
embodiment of a *decoding process* (3.1.22)

3.1.22
decoding process
process which takes as its input compressed image data and outputs a *continuous-tone image* (3.1.20)

3.1.23
dequantization
inverse procedure to quantization by which the *decoder* (3.1.21) recovers a representation of the DCT coefficients

3.1.24
downsampling
procedure by which the spatial resolution of a *component* (3.1.19) is reduced

3.1.25
encoder
embodiment of an *encoding process* (3.1.26)

3.1.26
encoding process
process which takes as its input a *continuous-tone image* (3.1.20) and outputs compressed image data

3.1.27
entropy-coded (data) segment
independently decodable sequence of entropy encoded *bytes* (3.1.11) of compressed image data

3.1.28
entropy decoder
embodiment of an *entropy decoding* (3.1.29) procedure

3.1.29
entropy decoding
lossless procedure which recovers the sequence of symbols from the sequence of *bits* (3.1.6) produced by the *entropy encoder* (3.1.30)

3.1.30
entropy encoder
embodiment of an *entropy encoding* (3.1.31) procedure

3.1.31
entropy encoding
lossless procedure which converts a sequence of input symbols into a sequence of *bits* (3.1.6) such that the average number of *bits* (3.1.6) per symbol approaches the entropy of the input symbols

3.1.32
extension image
synonym for *residual image* (3.1.61)

3.1.33
grayscale image
continuous-tone image (3.1.20) that has only one *component* (3.1.19)

3.1.34
high dynamic range
image or image data comprised of more than 8 bits per *sample* (3.1.62)

3.1.35
Huffman decoder
embodiment of a *Huffman decoding* (3.1.36) procedure

3.1.36
Huffman decoding
entropy decoding (3.1.29) procedure which recovers the symbol from each variable length code produced by the *Huffman encoder* (3.1.37)

3.1.37
Huffman encoder
embodiment of a *Huffman encoding* (3.1.38) procedure

3.1.38
Huffman encoding
entropy encoding (3.1.31) procedure which assigns a variable length code to each input symbol

3.1.39
implementation
realization of a specification

3.1.40
implementation under test
IUT
implementation (3.1.39) that is being evaluated for *conformance* (3.1.16)

3.1.41
intermediate dynamic range
image or image data comprised of more than 8 bits per *sample* (3.1.62)

3.1.42
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.

3.1.43
legacy codestream
collection of *markers* (3.1.51) and syntax elements defined by ISO/IEC 10918-1 bare any additional syntax elements defined by the ISO/IEC 18477 standard, 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 ISO/IEC 18477-3:2015, Annex A

3.1.44
legacy decoding path
collection of operations to be performed on the entropy coded data as described by ISO/IEC 10918-1 jointly with the Legacy Refinement scans before this data is merged with the residual data to form the final output image

3.1.45
legacy decoder
embodiment of a *decoding process* (3.1.20) conforming to ISO/IEC 10918-1, confined to the lossy DCT process and the baseline, sequential or progressive modes, decoding at most four components to 8 bits per component

3.1.46
legacy image
arrangement of sample values as described by applying the *decoding process* (3.1.20) described by ISO/IEC 10918-1 on the entropy coded data as defined by the said standard

3.1.47
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)

3.1.48
lossless coding
mode of operation which refers to any one of the *coding processes* (3.1.14) defined in ISO/IEC 18477-8 in which all of the procedures are *lossless* (3.1.47)

Note 1 to entry: See ISO/IEC 18477-8:2016, Annex H.

3.1.49
lossy
descriptive term for encoding and decoding processes which are not *lossless* (3.1.47)

3.1.50
low dynamic range
image or image data comprised of data with no more than 8 bits per *sample* (3.1.62)

3.1.51
marker
two-byte code in which the first byte is hexadecimal FF and the second byte is a value between 1 and hexadecimal FE

3.1.52
marker segment
marker (3.1.51) together with its associated set of parameters

3.1.53
pixel
collection of sample values in the spatial image domain having all the same sample coordinates

EXAMPLE A pixel may consist of three samples describing its red, green and blue value.

3.1.54
precision
number of *bits* (3.1.6) allocated to a particular *sample* (3.1.62) or DCT coefficient

3.1.55
procedure
set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

3.1.56
quantization value
integer value used in the quantization procedure

3.1.57
quantize
act of performing the quantization procedure for a DCT coefficient

3.1.58
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

3.1.59
residual image
sample values as reconstructed by inverse quantization and inverse DCT transformation applied to the entropy-decoded coefficients described by the *residual scan* (3.1.60) and residual refinement scans

3.1.60
residual scan
additional pass over the image data invisible to *legacy decoders* (3.1.45) which provides additive and/or multiplicative correction data of the legacy scans to allow reproduction of *high dynamic range* (3.1.34) or wide colour gamut data

3.1.61
refinement scan
additional pass over the image data invisible to *legacy decoders* (3.1.45) which provides additional least significant bits to extend the *precision* (3.1.54) of the DCT transformed *coefficients* (3.1.15)

3.1.62
sample
one element in the two-dimensional image array which comprises a *component* (3.1.19)

3.1.63
sample grid
common coordinate system for all *samples* (3.1.62) 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.

3.1.64
scan
single pass through the data for one or more of the *components* (3.1.19) in an image

3.1.65
scan header
marker segment (3.1.52) that contains a start-of-scan marker and associated scan parameters that are coded at the beginning of a *scan* (3.1.64)

3.1.66
source image
image used as input to an *encoder* (3.1.25)

3.1.67
superbox
box (3.1.10) that carries other boxes as payload data

3.1.68
table specification data
coded representation from which the tables used in the *encoder* (3.1.24) and *decoder* (3.1.21) are generated and their destinations specified

3.1.69
testing
process of evaluating *conformance* (3.1.16)

3.1.70
uniform quantization
method of reducing the *precision* (3.1.54) of DCT coefficients to enable more efficient entropy coding of them

3.1.71
upsampling
procedure (3.1.55) by which the spatial resolution of a *component* (3.1.19) is increased

3.2 Symbols

Nf	Number of components in an image
R_b	Additional bits in the HDR image. $8 + R_b$ is the sample precision of the reconstructed HDR or IDR image.

3.3 Abbreviated terms

ASCII	American standard code for information interchange
ATS	Abstract test suite
DCT	Discrete cosine transformation
ETS	Executable test suite
HDR	High dynamic range
IDR	Intermediate dynamic range
IUT	Implementation under test
JPEG	Joint photographic experts group
LDR	Low dynamic range
LSB	Least significant bit
MRSE	Mean relative square error
MSE	Mean square error
MSB	Most significant bit
PSNR	Peak signal to noise ratio
TMO	Tone mapping operator
TCS	Test codestream

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

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.
$\lvert x \rvert$	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.
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.

5 Conventions

The conformance files including codestreams, reference decoded images and descriptive files are supplied in the form of an electronic attachment, in compressed form. File locations given in this document are expressed relative to the top level directory tree within this compressed file. A Unix[1)] style file structure and delimiters are assumed.

This document contains instructions for the use of these files. No support can be provided by ITU | ISO/IEC beyond that offered in this document.

6 General description

6.1 Overview

The ISO/IEC 18477 series, also known as JPEG XT, consists of multiple parts each of which defines multiple coding tools. This document defines Abstract Test Suites (ATS) defining decoder conformance tests for ISO/IEC 18477-2, ISO/IEC 18477-6, ISO/IEC 18477-7, ISO/IEC 18477-8 and ISO/IEC 18477-9. Each part defines one or multiple profiles.

6.2 Parts and profiles

A *part* of ISO/IEC 18477 defines a set of coding tools designed to satisfy a common set of requirements, such as the lossy or lossless representation of images consisting of integer or floating point samples. A part defines a consistent syntax for the representation of data that falls into its requirements.

Profiles define a subset of technologies of a part that meets the needs of a given application within limits on parameters within a selected technology. Profiles limit the parameters that are available within a

1) Unix is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of these products.

given part, and hence constrain the available choices and coding options within such part. The full set of all possible options within a part is also denoted as *Full Profile.* Except for the full profile which is a superset of all other profiles, profiles do not define a hierarchy, and hence are not subsets of each other. While an implementation that is conforming to *Full Profile* is capable to decode every other profile, no other simple relation holds between the remaining profiles; they are independent of each other and only a superset of the *Full Profile*.

6.3 Decoders

Conforming implementations of decoders are not required to decode codestreams from all parts and profiles. JPEG XT decoders may only implement a subset of the parts, and/or for each part, a subset of the profiles available within this part.

6.4 Implementation conformance statement

Evaluation of conformance for a particular implementation may require a statement of the options that have been implemented. This will allow the implementation to be tested for conformance against only the relevant requirements. Such a statement is called an ICS (implementation conformance statement). This statement shall contain only options within the framework of requirements specified within one or multiple parts of ISO/IEC 18477.

6.5 Abstract test suites

The abstract test suites (ATS) define general tests for parts and/or profiles within parts of ISO/IEC 18477. Each ATS includes the following parts and are defined in Annex C:

a) test purpose: what the test requirement is;

b) test method: the procedures to be followed for the given ATS;

c) reference: the portion of the ITU | ISO/IEC document that is being tested by the given ATS.

6.6 Decoder conformance testing procedures

Procedures for testing decoders and the ETS that shall be used are specified in Annexes A and B. These procedures and ETS will allow an IUT to evaluate conformance to each part and profile within such part.

7 Copyright

These conforming files were originally developed by the parties indicated in the file `COPYRIGHT` and `README.License`. In particular, the original developers of these files and their respective companies or institutions, the editors and their companies/institutions, and ITU | ISO/IEC have disclaimed liability for any purposed use of these files or modifications thereof.

8 Conformance files availability and updates

The conformance test images provided as an electronic attachment to this document are the latest tested versions available at the date at which the text was released.

Annex A
(normative)

Decoder conformance testing procedures

A.1 General

This annex defines procedures to follow for determining whether a decoder is conforming to a particular profile within a particular part.

A.2 Decoder test procedure

A.2.1 General

The procedure defined herein will determine whether a decoder is conforming to a certain part and profile combination. The following steps for testing the set of codestreams are shown in the flow chart in Figure A.1.

— Select a profile and a part to test against.

— The part and profile define a TCS (test codestream set).

— The codestream and part define an error metric to select.

— Each codestream is decoded using the decoder under test.

— The decoded outputs are format converted if necessary.

— The difference between the decoded outputs and reference outputs are measured with the part-specific error metric.

— The measurements are compared with the limits for the particular image.

Each of these sets is defined in more detail in a later subsection of this annex. Failure to meet the tolerance limits for a single image results in the decoder failing to be conforming with the given profile and class being tested.

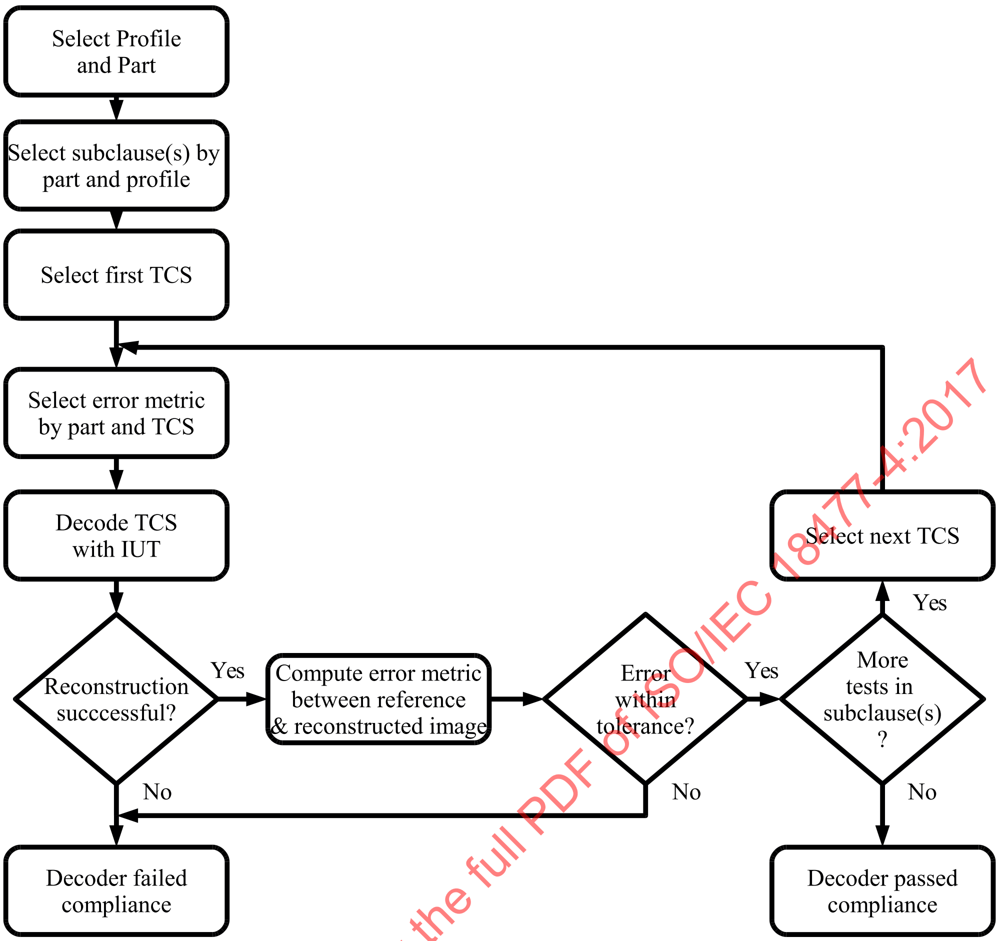

Figure A.1 — Decoder conformance test flow chart

A.2.2 Files for testing

A particular ETS defines the input codestreams, reference images, error metric and error tolerances. These are specified in Annex B for all parts and profiles.

A.2.3 Decoder settings

Decoders may have mechanisms for supporting various decompression settings. These may be set in the most advantageous way to achieve conformance. For example, a decoder with a "fast mode" and an "accurate mode" may be set to the "accurate mode" to determine conformance. These settings should be noted in any statement of conformance. Settings that allow the output resolution or spatial region of the reference decoded images to be matched may be changed for each decoded image. The same user controlled settings for accuracy or quantization reconstruction point of the DCT coefficients shall be used for all test codestreams.

A.2.4 Output file format conversion

A.2.4.1 General

The reference decoded images are provided in a specific file format defined below. In order to compare decoded images from the decoder under test with these images, several conversions may be necessary. These conversions may be done as post-processing steps outside of the decoder solely for determining conformance. There is no requirement for a conforming decoder to perform these processes as part of its normal operation. These conversion shall not introduce a quality change (either loss or gain) except as required by the specific conversions described in A.2.4.2.

For codestreams using the tools of ISO/IEC 18477-9, the output consists both of an image and an alpha channel. To assess the correctness of both the image and the alpha channel, the decoder shall either be instructed to generate two separate output files, one for the image data and one for the alpha channel, or an implementation-specific post-processing shall be used to separate image data and alpha channel data, and generate two files for the purpose of reference testing. There is no need for a decoder to generate two separate streams in the presence of an alpha channel to be conforming to ISO/IEC 18477-9, and creation of two separate files is only required for the purpose of testing.

A.2.4.2 Sample format conversion

Sample values reconstructed by decoders conforming to ISO/IEC 18477-1 and ISO/IEC 18477-6 are always integers. Sample values of decoders conforming to ISO/IEC 18477-8 and ISO/IEC 18477-9 may consist of integers depending on the parameters in the codestream. For the purpose of testing, it is of advantage to represent the integer output of the IUT in the PNM format defined in A.2.5 as ITU | ISO/IEC provide tools to measure on such files directly.

Samples of ISO/IEC 18477-2 and ISO/IEC 18477-7 are always, and samples of ISO/IEC 18477-8 and ISO/IEC 18477-9 may consist of floating point numbers. For the purpose of testing, it is of advantage to represent the floating point output of the IUT to the PNM format specified in A.2.5.

There is no requirement that a conforming decoder has to generate output to the specified format, and the representation of the output of the IUT in this format only facilitates the testing process.

The alpha channel data, if present, may require scaling and conversion to integer samples. While formally the alpha channel consists of floating point samples in the range [0,1], these samples shall be converted to integer values for the purpose of testing. For that, each sample value shall undergo the following transformation:

$C_i = \lfloor R_i \times (2^{R_b+8} - 1) + 0{,}5 \rfloor$ if the specified output transformation is a linear scaling

$C_i = R_i$ if the output transformation is a half-logarithmic map

Here, R_i is the reconstructed sample value of the alpha channel, as specified in ISO/IEC 18477-8:2016, Annex A, R_b is the bit-depth of the alpha channel, defined by the Output Conversion box as a sub-box of the Alpha Merging Specification box, and C_i is the input to the error metrics defined in A.2.6. In the first case, i.e. an alpha channel converted to integer samples, the error metric of A.2.6.1 shall be used, in the latter case, the error metric of A.2.6.2 shall be used.

Decoder implementations of ISO/IEC 18477-9 may already include such a conversion of the alpha channel data or may, at their discretion, skip any linear output transformation. They may, hence, avoid a scaling of the alpha channel data to [0,1], as specified in ISO/IEC 18477-9, and back to integer, as necessary by the above formulae in this text. There is no requirement that an ISO/IEC 18477-9 decoder implementation shall generate a separate alpha channel or shall scale it to a particular range. Scaling and conversion are only required for the purpose of testing.

NOTE Conversion from YC_bC_r to RGB and clipping to range are a mandatory part of the ISO/IEC 18477 series specifications.

A.2.5 Reference components file format

A.2.5.1 General

This subclause describes the file format, called PNM, of the reference images used for comparison with the output of the decoder under test. The decoder under test is not required to produce this particular file format, though it is advantageous to perform a conversion to this file format for testing purposes as ITU | ISO/IEC provides test tools that are able to decode this format. Any necessary conversion to this format, as specified by A.2.4, may be applied.

The format consists of a header and raw data, concatenated to a single file.

A.2.5.2 Header format

The format of the header consists of

- two identifier bytes that specify the data format and encoding:
  - which are the ASCII codes for "P6" (hex 0x50 0x36) for three-component integer sample images;
  - the ASCII codes "P5" (hex 0x50 0x35) for one-component (grayscale) integer sample images;
  - the ASCII codes "PF" (hex 0x50 0x46) for three-component floating-point sample images;
  - the ASCII codes "Pf" (hex 0x50 0x66) for one-component floating point sample images;
- followed by any number of white space (ASCII 32, ASCII 8, ASCII 13 or ASCII 10, i.e. blank space, TAB, CR or LF),
- a width in pixels formatted as ASCII encoded decimal number,
- any number of white space,
- a height in pixels formatted as ASCII encoded decimal number,
- for integer sample formats:
  - any number of white space;
  - the maximum sample value, i.e. $2^{R_b+8}-1$ where $R_b + 8$ is the bit precision of the integer samples;
  - a **single** ASCII line feed (hex 0x0a);
- for floating point sample formats:
  - any number of white spaces;
  - a floating point scale value, represented as decimal fraction. This number serves no particular purpose in this document and, while present, shall be ignored;
  - a single white space;
- the raw data formatted according to the following subclause follows this header immediately.

A.2.5.3 Data format

The binary data appears immediately after the line feed (hex 0x0a) byte in the header. The data is stored with the most significant byte first, either in the IEC 60559 single-precision format for floating point images or in binary two's complement representation for integer sample images, sign extended to either 1 byte, 2 bytes or 4 bytes. Components are interleaved in this format, in the order "Red, Green, Blue" or "X, Y, Z", depending on the colour space of the image

A.2.6 Compare decoded and formatted components with reference components

A.2.6.1 Selection of the error metric

Once the decoded image has been converted to a suitable target format, it is compared with the reference image. This document defines two error metrics to test the validity of the decoded image. $PSNR_{MSE}$, defined in A.2.6.2 shall be used to assess the correctness of decoded images consisting of integer samples, and hence shall be used to test implementations of ISO/IEC 18477-6, and some configurations of ISO/IEC 18477-8 and ISO/IEC 18477-9.

The error metric $PSNR_{MRSE}$ defined in A.2.6.3 shall be used to assess the correctness of decoded images consisting of floating point samples, and hence shall be used to test implementations of ISO/IEC 18477-7, and some configurations of ISO/IEC 18477-8 and ISO/IEC 18477-9.

The reference image is recorded in the format specified in A.2.5. While there is no particular requirement that the decoded image is stored in the same format, it is helpful to perform this conversion because ITU | ISO/IEC provide a command line tool that accepts this format and allows to carry out the computations in this subclause.

A.2.6.2 Error metric for integer sample data

The error metric specified in this subclause shall be used to assess the correctness of decoded image data consisting of integer samples, or of alpha channel data that uses a linear output conversion and has been scaled to integers. In the first step, the mean square error shall be computed as Formula (A.1):

$$MSE = 1/N \times \sum_i (X_i - Y_i)^2 \qquad (A.1)$$

where

X_i is the i-th sample value of the reference image;

Y_i is the i-th sample value at the same position and of the same component in the decoded image.

The sum runs over all samples, i.e. all pixels and all components within each pixel, and N is the total number of samples, i.e. the number of pixels times the number of components.

In the second step, the $PSNR_{MSE}$ shall be computed as Formula (A.2):

$$PSNR_{MSE} = -10\log_{10} [MSE/(2^{R_b+8}-1)^2] \qquad (A.2)$$

where

$\log_{10}$ is the logarithm to the base of 10;

MSE is the mean square error as computed in the first step;

$R_b + 8$ is the output bit precision of the decoded image.

For image data, R_b is defined by the Output Conversion box as a subbox of the Merging Specification box, for alpha channels, R_b is found in the Output Conversion subbox of the Alpha Merging specification box. $PSNR_{MSE}$ is then the final output of this error metric.

A.2.6.3 Error metric for floating point sample data

The error metric specified in this subclause shall be used to test the correctness of decoded image data consisting of floating point samples, or alpha channel data that has been decoded with the half-logarithmic map as output conversion. In the first step, the mean relative square error shall be computed as Formula (A.3):

$$MRSE = 1/N \times \sum_i (X_i - Y_i)^2/(X_i^2 + Y_i^2) \qquad (A.3)$$

where

X_i is the i-th sample value of the reference image;

Y_i is the i-th sample value at the same position and of the same component of the decoded image.

The sum runs over all sample values, i.e. all components and all sample positions for which the denominator $\left(X_i^2 + Y_i^2\right)$ is non-zero. Equivalently, the value of the quotient under the sum shall be taken as zero whenever both numerator and denominator are zero. In the above, N is the number of samples, i.e. the number of pixels times the number of components.

In the second step, the $PSNR_{MRSE}$ shall be computed as Formula (A.4):

$$PSNR_{MRSE} = -10\log_{10} MRSE \tag{A.4}$$

where

$\log_{10}$ is the logarithm to the base of 10;

MRSE is the mean relative square error computed in the first step.

$PSNR_{MRSE}$ is then the final output of this error metric.

Annex B
(normative)

Decoder conformance tests

B.1 General

This annex specifies the abstract test suites and executable test suites that will be used in the conformance test procedures from Annex A.

B.2 Abstract test suites

B.2.1 General

The lists in this subclause are used to define the decoder ETS and could be used to develop additional encoder or decoder ETSs.

B.2.2 Syntax and compressed data order

The purpose of this test is to check the ability of a decoder to decode codestreams with optional boxes and markers, box and marker values and markers in various locations in the codestream.

The test method is to encode codestreams with varying marker locations and variations of markers that, despite varying implementation details, shall decode to identical images on the same implementation. For example, the location of a box or marker shall not have an impact on the reconstructed image, regardless of other implementation choices. Parameters and existence of boxes or markers may be limited by the part and profile being tested.

Specific test items include:

— locations of markers and boxes in the codestream, optional markers and boxes in different positions of the codestream;

— priority of markers and boxes. Some boxes override other boxes, and some boxes may be placed either at top-level or as a subbox of other boxes. Specifically, many boxes can be either placed into the Merging Specification box, or top-level, where the former overrides the latter;

— proper parsing of segmented boxes, i.e. boxes that extend over various JPEG Extension marker segments.

References are given by ISO/IEC 18477-3, box-based file format.

B.2.3 Huffman decoding and scan types

The test purpose is to evaluate the correct operation of the implementation of the Huffman decoder and the scan types within the IUT.

The test method uses lossy or lossless compressed images using various scan types, and/or multiple scans over the same data. Specific test options include:

— verification of correct decoding of byte-stuffing;

— verification of baseline, extended sequential, progressive, DCT-bypass-sequential, DCT-bypass large range, DCT-bypass progressive, refinement-sequential and refinement-progressive scan types;

— verification of correct termination of Huffman coding;

— combination of various options.

References: baseline, extended sequential and progressive scan types are specified in ISO/IEC 10918-1. Refinement-sequential and refinement-progressive scan types are defined in ISO/IEC 18477-6. DCT-bypass sequential, DCT-bypass sequential, DCT-bypass large-range sequential and DCT-bypass progressive scan types are specified in ISO/IEC 18477-8.

B.2.4 Quantization

The purpose of this test is to test the accuracy of the quantization implementation of the IUT and the correctness of the implementation, especially in the presence of refinement scans.

The test method is to decode several different codestreams with and without refinement scans in the base or extension layer with other options staying the same. Especially, a codestream with a residual bit-precision of P = 12 is equivalent to a residual codestream with P = 8 and R_r = 4 residual refinement scans.

Specific test options include the following.

— Decode codestreams with various quantization matrices and testing against error bounds of the decoded images.

— Test two images with equivalent quantization configuration but varying number of refinement scans. Despite implementation differences, such codestreams shall reconstruct to identical images on the same decoder implementation.

References: Inverse quantization is specified in ISO/IEC 10918-1. Refinement scans and quantization in the presence of refinement scans is specified in ISO/IEC 18477-6.

B.2.5 Inverse DCT, IDCT, FDCT and DCT bypass

The purpose of this test is to test the accuracy of the inverse DCT, and the correctness of the fixed-point and integer DCT, as well as the correctness of the DCT bypass.

The test method feeds codestreams with an all-unity quantization matrix into the IUT and tests the output against error bounds to test the precision of the DCT implementation for ISO/IEC 18477-2, ISO/IEC 18477-6 and ISO/IEC 18477-7. For ISO/IEC 18477-8, the reconstructed output shall be exactly identical to that of the reference decoder and various DCT types (IDCT, FDCT and DCT-bypass) specified in this document. This test shall be combined with a test against the error bounds of the DCT specified in ISO/IEC 10918-2.

Specific items to test include:

— test of the precision of the DCT following the procedures and error bounds specified in ISO/IEC 10918-2 for the baseline decoder of ISO/IEC 18477-2, ISO/IEC 18477-6 and ISO/IEC 18477-7;

— test of the precision of the DCT with the codestreams provided in this document against the error bounds also defined here. This tests the extension layer decoding of ISO/IEC 18477-2, ISO/IEC 18477-6 and ISO/IEC 18477-7;

— test of the correctness of the FDCT, IDCT and DCT-bypass of ISO/IEC 18477-8. Images decoded by the IUT shall be identical to the reference images provided in this document.

References: ISO/IEC 10918-1 defines the DCT, ISO/IEC 10918-2 specifies the baseline decoder error bounds and this document specifies error bounds for residual decoding. ISO/IEC 18477-8 specifies the IDCT, FDCT and DCT-bypass.

B.2.6 Inverse decorrelation transformation and colour transformation

The purpose of this test is to test the accuracy of the inverse colour transformation and inverse decorrelation transformations present in the decoder model.

The test method feeds codestreams with fine quantization settings into the IUT and tests the output against the error bounds to test the precision of the colour transformations and inverse decorrelation transformations for ISO/IEC 18477-2, ISO/IEC 18477-6 and ISO/IEC 18477-7. For ISO/IEC 18477-8, the reconstructed output shall be exactly identical to that of the reference decoder.

Specific items to test include:

— test of the base decorrelation transformation, identity and YC_bC_r to RGB transformation;

— test for the base colour transformation, as required if colourspace of the base image is different from the colour space of the full decoded image;

— test of the residual decorrelation transformation.

References: ISO/IEC 18477-2 and ISO/IEC 18477-6 specify several transformations that could be employed. ISO/IEC 18477-7 specifies additional linear transformations in the residual decoding path. ISO/IEC 18477-8 specifies fixed point based transformations that approximate the floating point based transformations in other parts.

B.3 Executable test suites (ETS)

B.3.1 General

The executable test suites are the embodiment of the ATS. Commonly, several ATS are embodied into one ETS. This subclause defines nine ETS, namely, one for ISO/IEC 18477-2, one for ISO/IEC 18477-6, five for ISO/IEC 18477-7 (Profiles A, B, C, D and full profile), two for ISO 18477-8 and two for ISO/IEC 18477-9. The tolerances are defined in dB PSNR, where PSNR is either given by the integer MSE-based $PSNR_{MSE}$ value specified in A.2.6.1 or the floating-point MRSE-based $PSNR_{MRSE}$ specified in A.2.6.2.

Each ETS consists of codestreams, reference decoded images, a textual description of the contents of the codestream and tolerance values for MSE or MRSE-based PSNR. In addition, some information is provided about the test codestream which may aid correction of a non-conforming decoder. This information consists of a table listing of the markers and boxes in the codestream, the offset into the codestream where those markers and boxes are found, and the value of the parameters of those markers and boxes.

ITU | ISO/IEC provides two additional software packages in source code included in the electronic attachment to this document to aid testing.

B.3.2 Codestream parser utility (jpgcodestream.py)

The `jpgcodestream.py` utility consists of a set of python™[2)] scripts that decode ISO/IEC 10918-1 and ISO/IEC 18477 conforming codestreams and list their contents on the console. A python™ interpreter suitable to execute these scripts can be found at www.python.org. The codestream parser is called as follows:

```
jpgcodestream.py <codestream>
```

where <codestream> shall be substituted by the path to the JPEG XT codestream to analyse. The utility lists its output to the console.

2) Python is the trade name of a product supplied by the Python Software Foundation. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

B.3.3 Measurement tool (difftest_ng)

B.3.3.1 General

The `difftest_ng` tool provides implementations of the error metrics specified in A.2.6.1 and A.2.6.2. It also implements a decoder of the PNM file format defined in A.2.4. It can also convert and decode files between various formats. Readers may utilize this utility to implement the ETS discussed in this subclause and the following clauses. A full discussion of the `difftest_ng` utility is beyond the scope of this subclause, only the command line arguments required to implement the metrics will be given.

There is no requirement to use this particular tool to implement the ETS; any other measurement tool implementing the error metrics of A.2.6.1 and A.2.6.2 is suitable as well. The `difftest_ng` tool is only provided by ITU | ISO/IEC to convenience testing.

B.3.3.2 Compilation of difftest_ng

Compilation of `difftest_ng` on Unix/Linux/MacOs[3] can be performed in the presence of the gcc/g++ compiler suite, the GNU make utility and a bash-compatible command line. In the presence of these utilities, compilation of `difftest_ng` can be performed by the following steps. First, configure the compilation environment by entering

```
./configure
```

in the `difftest_ng` directory contained in the electronic attachment. This will detect compiler specifics and the available software packages on the target infrastructure. Afterwards, `difftest_ng` is compiled by entering

```
make
```

on the same directory.

For Windows™[4] operating systems, a Visual Studio™[3] configuration file is included as well. This configuration file shall be loaded, and compilation is immediate through the "Build" menu of this compiler suite.

B.3.3.3 Measuring PSNR$_{MSE}$ with difftest_ng

To measure the MSE-based PSNR as defined in A.2.6.1 for integer-based sample formats, `difftest_ng` shall be called as follows:

```
difftest_ng --psnr reference.ppm decoded.ppm
```

where `reference.ppm` is the reference image of the ETS subtest to be executed contained in the electronic attachment, and `decoded.ppm` is the decoded image output of the IUT. With the above command line, `difftest_ng` accepts input images in the PNM format specified in A.2.4.

B.3.3.4 Measuring PSNR$_{MRSE}$ with difftest_ng

To measure the MRSE-based PSNR as defined in A.2.6.2 for floating-point based sample formats, `difftest_ng` shall be called as follows:

```
difftest_ng --mrse  reference.pfm decoded.pfm
```

3) Unix, Linux and MacOs are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC these products.

4) Windows and Visual Studio are the trade names of products supplied by Microsoft. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO or IEC of the product named. Equivalent products may be used if they can be shown to lead to the same results.

where `reference.pfm` is the reference image of the ETS subtest to be executed contained in the electronic attachment, and `decoded.pfm` is the decoded image output of the IUT. With the above command line, `difftest_ng` accepts input images in the PNM format specified in A.2.4.

B.3.4 References and tolerances for ISO/IEC 18477-1

Table B.1 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-1. The error metric to be used for these tests is the MSE-based PSNR specified in A.2.6.1.

Table B.1 — ISO/IEC 18477-1 test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MSE}$	Notes
bg-01.jpg	bg-01.ppm	High-quality compression with 444 subsampling, extended Huffman process, YC_bC_r to RGB conversion	42 dB	
of-02.jpg	of-02.ppm	High quality progressive mode	40 dB	
ld-03.jpg	ld-03.ppm	Component decorrelation control marker and restart markers	47 dB	The conversion to YC_bC_r is disabled.
mr-04.jpg	mr-04.ppm	Upsampling of 420 subsampled chroma components	39 dB	Note that ISO/IEC 18477-1 defines the upsampling process.
bg-05.jpg	bg-05.ppm	Upsampling of 422 subsampled chroma components	32 dB	
mr-06.jpg	mr-06.ppm	Mixed 422 and 440 subsampling	38 dB	
hz-07.jpg	hz-07.ppm	Grayscale single component, high-quality	48 dB	

B.3.5 References and tolerances for ISO/IEC 18477-2

Table B.2 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-2. The error metric to be used for these tests is the MRSE-based PSNR specified in A.2.6.2.

Table B.2 — ISO/IEC 18477-2 test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MRSE}$	Notes
bg-01.jpg	bg-01.pfm	Global tone mapping operator, medium quality, parametric function for luminance factor	11 dB	
ld-02.jpg	ld-02.pfm	Local tone mapping operator, lookup for luminance scale factor	25 dB	
mr-03.jpg	mr-03.pfm	Subsampling in the base layer	17 dB	
of-04.jpg	of-04.pfm	Grayscale, lookup for multiplicator	19 dB	
bg-05.jpg	bg-05.pfm	Grayscale, parametric function as factor	15 dB	

B.3.6 References and tolerances for ISO/IEC 18477-6

Table B.3 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-6. The error metric to be used for these tests is the MSE-based PSNR specified in A.2.6.1.

Table B.3 — ISO/IEC 18477-6 test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MSE}$	Notes
hz-01.jpg	hz-01.ppm	16 bpp integer, medium quality	33 dB	
on-02.jpg	on-02.ppm	Subsampling in the base layer	33 dB	
hz-03.jpg	hz-03.ppm	Refinement scans in the base layer	46 dB	
hz-04.jpg	hz-04.ppm	Residual refinement scans, coding in XYZ	34 dB	
on-05.jpg	on-05.ppm	Residual refinement scans, coding in XYZ with colour transformation matrix	31 dB	
hz-06.jpg	hz-06.ppm	12 bpp integer image, 12-bit residual scan	34 dB	
on-07.jpg	on-07.ppm	10 bpp integer image, subsampling, residual refinement scan	31 dB	

B.3.7 References and tolerances for ISO/IEC 18477-7

B.3.7.1 General

ISO/IEC 18477-7 defines four profiles, and the ETS is structured along those profiles. Decoder implementations only need to test against those profiles they claim to conform to.

B.3.7.2 References and tolerances for ISO/IEC 18477-7 Profile A

Table B.4 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-7 Profile A. The error metric to be used for these tests is the MRSE-based PSNR specified in A.2.6.2.

Table B.4 — ISO/IEC 18477-7 Profile A test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MRSE}$	Notes
bg-01.jpg	bg-01.pfm	Local TMO	11 dB	
ld-02.jpg	ld-02.pfm	Global TMO	22 dB	
mr-03.jpg	mr-03.pfm	Subsampling in the base layer	18 dB	
of-04.jpg	of-04.pfm	Grayscale, local TMO	19 dB	
bg-05.jpg	bg-05.pfm	Grayscale, global TMO	16 dB	

B.3.7.3 References and tolerances for ISO/IEC 18477-7 Profile B

Table B.5 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-7 Profile B. The error metric to be used for these tests is the MRSE-based PSNR specified in A.2.6.2.

Table B.5 — ISO/IEC 18477-7 Profile B test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MRSE}$	Notes
bg-01.jpg	bg-01.pfm	Global TMO	10 dB	
ld-02.jpg	ld-02.pfm	Local TMO	20 dB	
mr-03.jpg	mr-03.pfm	Subsampling in the base layer	17 dB	
of-04.jpg	of-04.pfm	Subsampling in the base layer	16 dB	
mr-05.jpg	mr-05.pfm	Black and white image	18 dB	

B.3.7.4 References and tolerances for ISO/IEC 18477-7 Profile C

Table B.6 lists the codestreams and tolerances for testing implementations against ISO/IEC 18477-7 Profile C. The error metric to be used for these tests is the MRSE-based PSNR specified in A.2.6.2.

Table B.6 — ISO/IEC 18477-7 Profile C test files, references and tolerances

TCS	Reference file	Textual description	Minimum allowable $PSNR_{MRSE}$	Notes
bg-01.jpg	bg-01.pfm	Local TMO	11 dB	
ld-02.jpg	ld-02.pfm	12-bit residual	16 dB	
mr-03.jpg	mr-03.pfm	Subsampling in the base image	14 dB	
of-04.jpg	of-04.pfm	Black and white, refinement scan in the base layer	22 dB	

