ETSI TS 103 433-2 V1.1.1 (2018-01)

TECHNICAL SPECIFICATION

High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 2: Enhancements for Perceptual Quantization (PQ) transfer function based High Dynamic Range (HDR) Systems (SL-HDR2)

OPERATING EUROVISION

Reference

DTS/JTC-040-2

Keywords

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Foreword

This Technical Specification (TS) has been produced by ETSI 3rd Generation Partnership Project (3GPP).

The present document is part 2 of a multi-part deliverable. Full details of the entire series can be found in part 1 [1].

NOTE: The EBU/ETSI JTC Broadcast was established in 1990 to co-ordinate the drafting of standards in the specific field of broadcasting and related fields. Since 1995 the JTC Broadcast became a tripartite body by including in the Memorandum of Understanding also CENELEC, which is responsible for the standardization of radio and television receivers. The EBU is a professional association of broadcasting organizations whose work includes the co-ordination of its members' activities in the technical, legal, programme-making and programme-exchange domains. The EBU has active members in about 60 countries in the European broadcasting area; its headquarters is in Geneva.

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Modal verbs terminology

In the present document "**shall**", "**shall not**", "**should**", "**should not**", "**may**", "**need not**", "**will**", "**will not**", "**can**" and "**cannot**" are to be interpreted as described in clause 3.2 of the ETSI Drafting Rules (Verbal forms for the expression of provisions).

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Introduction

Motivation

Today High Efficiency Video Coding (HEVC) enables first Ultra HD broadcast services (also referred as "4K" resolution) via existing DVB specifications.

The goal of ETSI TS 103 433-1 [1] V1.2.1, SL-HDR1, was to standardize a single layer HDR system addressing direct backwards compatibility i.e. a system leveraging SDR distribution networks and services already in place and that enables high quality HDR rendering on HDR-enabled CE devices including high quality SDR rendering on SDR CE devices.

The goal of the present document is to specify enhancements for single layer Perceptual Quantization (PQ) transfer function based HDR systems, enabled by signal processing blocks that are similar/the same to those in SL-HDR1. Similar to SL-HDR1, these enhancements will be enabled by use of dynamic metadata and a post processor in the Consumer Electronics device.

Pre-processing

At the distribution stage, an incoming HDR signal is analysed and content-dependent dynamic metadata is produced. This dynamic metadata can be produced in an automatic process or in a manual process where the image quality resulting of the metadata that has been set manually is judged on an SDR grading monitor. This dynamic metadata can be used to create an optimal picture for a display that has different characteristics, most noticeably a different maximum luminance, than the display used when grading the HDR content. The HDR signal is encoded with any distribution codec (e.g. HEVC as specified in part 1 [1], Annex A) and carried throughout an HDR distribution network with accompanying metadata conveyed on a specific channel or embedded in an HDR bitstream. The dynamic metadata can for instance be carried in an SEI message when used in conjunction with an HEVC codec. The pre-processor that produces dynamic metadata is not a normative requirement of the present document. Nonetheless, the pre-processor is expected to produce a dynamic metadata stream matching the syntax specified in Annex A and Annex B.

Post-processing

The post-processing stage occurs just after HDR bitstream decoding. The post-processing takes as input an HDR video frame and associated dynamic metadata and the characteristic of the attached HDR compliant rendering device in order to optimize the HDR picture for the rendering device as specified in clause 7.

Structure of the present document

The present document is structured as follows. Clause 1 provides the scope of the current document. Clause 2 provides references used in the present document. Clause 3 gives essential definitions, symbols and abbreviations used in the present document. Clause 4 provides information on the end to end system. Clause 5 details the architecture of the HDR system. Clause 6 specifies the format of the content-based dynamic metadata common to systems based on ETSI TS 103 433 multi-part documents. Specifically to the present document, the metadata are produced during the HDR-to-SDR decomposition stage and they enable reconstruction of the SDR signal from the decoded HDR signal using those metadata. Clause 7 specifies the reconstruction process of the SDR signal and an HDR signal that is adapted to the maximum luminance of the presentation display. The dynamic metadata format specified in clause 6 is normatively mapped from SEI messages representative of SL-HDR system that are specified for HEVC and AVC respectively in Annex A and Annex B. Informative Annex C and Annex D provide information on an HDR-to-SDR decomposition process, and a gamut mapping process. Informative Annex E describes a way to transfer dynamic metadata by embedding it in the video transferred over a CE digital video interface. Informative Annex F proposes a recovery procedure when dynamic metadata are detected as missing by the post-processor during the HDR signal reconstruction. The recovery procedure may also be applied in case it is desirable to replace the original metadata by a fixed tone mapping function, e.g. when graphics overlays are inserted on the decoded video by a mid-device (e.g. STB) which transmits SL-HDR reconstruction metadata as well as the mixed video to an SL-HDR capable TV. Eventually, informative Annex G gives reference to a standard mechanism to carry SL-HDR reconstruction metadata through interfaces and Annex H provides a recommendation on the maximum presentation display luminance that display adaptation can be used with.

The structure of the present document is summarized in Table 1.

Table 1: Structure of the present document

Clause/Annex #	Descriptionfigure	Normative/Informative (in the present document)
Clause 1	Scope of the document	Informative
Clause 2	References used in the document	Normative/Informative
Clause 3	Definitions, symbols, abbreviations	Informative
Clause 4	End-to-end system	Informative
Clause 5	Architecture of the HDR system	Informative
Clause 6	Metadata format abstraction layer (agnostic to the distribution format)	Normative
Clause 7	HDR-to-HDR/SDR reconstruction process	Normative
Annex A	SL-HDR reconstruction metadata using HEVC	Normative
Annex B	SL-HDR reconstruction metadata using AVC	Normative
Annex C	HDR-to-SDR decomposition principles and considerations	Informative
Annex D	Gamut mapping	Informative
Annex E	Embedded data on CE digital video interfaces	Informative
Annex F	Error-concealment and recovery procedure	Informative
Annex G	ETSI TS 103 433 signalling in CTA-861-G	Informative
Annex H	Minimum and maximum value of L_{pdisp} for display adaptation	Informative

1 Scope

The present document specifies the HDR-to-HDR/SDR content-based dynamic metadata and the post-decoding process enabling reconstruction from the specified metadata and an HDR signal of an SDR signal (100 cd/m^2 or less) or an HDR signal with a maximum luminance ranging from 100 cd/m^2 to a maximum luminance that is higher than that of the original HDR signal. This reconstruction process is typically invoked in a Consumer Electronics device such as a TV set, a smartphone, a tablet, or a Set Top Box. Besides, it provides information and recommendations on the usage of the described HDR system.

2 References

2.1 Normative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at https://docbox.etsi.org/Reference/.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are necessary for the application of the present document.

[1] ETSI TS 103 433-1 (08-2017): "High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices; Part 1: Directly Standard Dynamic Range (SDR) Compatible HDR System (SL-HDR1)".

[2] Recommendation ITU-R BT.709-6 (06-2015): "Parameter values for HDTV standards for production and international programme exchange".

[3] Recommendation ITU-R BT.2020-2 (10-2015): "Parameter values for ultra-high definition television systems for production and international programme exchange".

[4] Recommendation ITU-T H.264 (04-2017): "Advanced video coding for generic audiovisual services".

[5] Recommendation ITU-T H.265 (12-2016): "High efficiency video coding".

[6] SMPTE ST 2084:2014: "High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays".

[7] SMPTE ST 2086:2014: "Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images".

2.2 Informative references

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the referenced document (including any amendments) applies.

NOTE: While any hyperlinks included in this clause were valid at the time of publication, ETSI cannot guarantee their long term validity.

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

[i.1] CTA Standard CTA-861.3, January 2015: "HDR Static Metadata extensions".

[i.2] CTA Standard CTA-861-G, November 2016: "A DTV Profile for Uncompressed High Speed Digital Interfaces".

[i.3] Recommendation ITU-R BT.2035: "A reference environment for evaluation of HDTV program material or completed programmes".

[i.4] Ross N. Williams: "A Painless Guide to CRC Error Detection Algorithms," Version 3, 19 August 1993.

NOTE: Available at http://www.ross.net/crc/crcpaper.html.

[i.5] SMPTE Engineering Guideline EG 28-1993: "Annotated Glossary of Essential Terms for Electronic Production".

[i.6] SMPTE ST 2094-20:2016: "Dynamic Metadata for Color Volume Transform - Application #2".

[i.7] SMPTE ST 2094-30:2016: "Dynamic Metadata for Color Volume Transform - Application #3".

[i.8] ETSI TS 103 433 (all parts): "High-Performance Single Layer High Dynamic Range (HDR) System for use in Consumer Electronics devices".

3 Definitions, symbols, abbreviations and conventions

3.1 Definitions

For the purposes of the present document, the following terms and definitions apply:

colour correction: adjustment of the luma and chroma components of a signal derived from the HDR signal in order to avoid hue shift and preserve the colour look of the HDR signal in the SDR signal

colour volume: solid in colorimetric space containing all possible colours a display can produce

decomposed picture: SDR picture derived from the HDR-to-SDR pre-processing stage

NOTE: Type of pre-processed picture.

display adaptation: adaptation of a video signal to the characteristics of the targeted Consumer Electronics display (e.g. maximum luminance of the CE display)

dynamic metadata: metadata that can be different for different portions of the video and can change at each associated picture

gamut: complete subset of colours which can be represented within a given colour space or by a certain output device

NOTE: Also known as colour gamut.

gamut mapping: mapping of the colour space coordinates of the elements of a source image to colour space coordinates of the elements of a reproduction

NOTE: Gamut mapping intent is not to change the dynamic range of the source but to compensate for differences in the source and output medium colour gamut capability.

High Dynamic Range (HDR) system: system specified and designed for capturing, processing, and reproducing a scene, conveying the full range of perceptible shadow and highlight detail, with sufficient precision and acceptable artefacts, including sufficient separation of diffuse white and specular highlights

luma: linear combination of non-linear-light (gamma-corrected) primary colour signals

luminance: objective measure of the visible radiant flux weighted for colour by the CIE Photopic Spectral Luminous Efficiency Function [i.5]

luminance mapping: adjustment of the luminance representative of a source signal to the luminance of a targeted system

post-production: part of the process of filmmaking and video production gathering many different processes such as video editing, adding visual special effects, transfer of colour motion picture film to video

NOTE: The pre-processed picture is generated during the post-production stage at the encoding site.

pre-processed picture: output picture of SL-HDR pre-processing stage

presentation display: display that the IRD outputs to

reconstructed picture: output picture of SL-HDR post-processing stage

Single Layer High Dynamic Range (SL-HDR) system: system implementing at least one of the parts of the ETSI TS 103 433 multi-part document [i.8]

source picture: input picture of SL-HDR pre-processing stage

NOTE: Typically an HDR picture coming from post-production facilities.

Standard Colour Gamut (SCG): chromaticity gamut equal to the chromaticity gamut defined by Recommendation ITU-R BT.709-6 [2]

Standard Dynamic Range (SDR) system: system having a reference reproduction using a luminance range constrained by Recommendation ITU-R BT.2035 [i.3], section 3.2

NOTE: Typically no more than 10 stops.

Supplemental Enhancement Information (SEI) message: carriage mechanism defined in Recommendation ITU-T H.264 [4] and Recommendation ITU-T H.265 [5] that is intended to assist in processes related to decoding, display or other purposes

target picture: picture graded on an SDR mastering display

Wide Colour Gamut (WCG): chromaticity gamut larger than the chromaticity gamut defined by Recommendation ITU-R BT.709-6 [2]

3.2 Symbols

3.2.1 Arithmetic operators

For the purposes of the present document, the following arithmetic operators apply:

$+$	Addition
$-$	Subtraction (as a two-argument operator) or negation (as a unary prefix operator)
$\times$	Multiplication, including matrix multiplication
x^y	Exponentiation. Specifies x to the power of y. In other contexts, such notation is used for superscripting not intended for interpretation as exponentiation
$/$	Integer division with truncation of the result toward zero. For example, 7/4 and -7/-4 are truncated to 1 and -7/4 and 7/-4 are truncated to -1
$\div$	Used to denote division in mathematical equations where no truncation or rounding is intended
$\frac{x}{y}$	Used to denote division in mathematical equations where no truncation or rounding is intended

3.2.2 Mathematical functions

For the purposes of the present document, the following mathematical functions apply:

Abs(x) $\begin{cases} x & , \quad x \geq 0 \\ -x & , \quad x < 0 \end{cases}$

Clip3(x; y; z) $\begin{cases} x & , \quad z < x \\ y & , \quad z > y \\ z & , \quad \text{otherwise} \end{cases}$

Floor(x) the largest integer less than or equal to x.*ln*(x) natural logarithm of x

log10(x) the base-10 logarithm of x

Min(x ; y) $\begin{cases} x & , \quad x \leq y \\ y & , \quad x > y \end{cases}$

Max(x ; y) $\begin{cases} x & , \quad x \geq y \\ y & , \quad x < y \end{cases}$

x = y..z x takes on integer values starting from y to z, inclusive, with x, y, and z being integer numbers and z being greater than y

3.3 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AVC Advanced Video Coding
CE Consumer Electronics
CIE Commission Internationale de l'Eclairage
CRC Cyclic Redundancy Check
EDID Extended Display Identification Data
EOTF Electro-Optical Transfer Function
HDMI High-Definition Multimedia Interface
HDR High Dynamic Range
HEVC High Efficiency Video Coding
IRD Integrated Receiver Decoder
LSB Least Significant Bit
LUT Look-Up Table
MDCV Mastering Display Colour Volume
MSB Most Significant Bit
PQ Perceptual Quantization
RGB Red Green Blue colour model
SCG Standard Colour Gamut
SDRLUT Standard Dynamic Range Look-Up Table
SEI Supplemental Enhancement Information (as in AVC and HEVC)
SL-HDR Single Layer High Dynamic Range
SL-HDRI Single Layer High Dynamic Range Information
SMPTE Society of Motion Picture and Television Engineers
STB Set Top Box
VSVDB Vendor-Specific Video Data Block
WCG Wide Colour Gamut

3.4 Conventions

Unless otherwise stated, the following convention regarding the notation is used:

- Variables specified in the present document are indicated by bold Arial font 9 points lower camel case style e.g. **camelCase**. All those variables are described in clause 6.
- Internal variables of the present document are indicated by italic Cambria math font 10 points style e.g. *variable*.
- Structures of syntactic elements or structures of variables are indicated by Arial font 9 points C-style with parentheses e.g. structure_of_variables( ). Those structures are defined in clause 6 of part 1 [1], Annex A of part 1 [1], and Annex B of part 1 [1].
- Bitstream syntactic elements are indicated by bold Arial font 9 points C-style e.g. **syntactic_element**. All those variables are defined in Annex A of part 1 [1] and in Annex B of part 1 [1].
- Functions are indicated as $func(x)$.
- Tables are indicated as $table[idx]$.

4 End-to-end system

Figure 1 shows an end-to-end workflow supporting content production and delivery to HDR and SDR displays and to displays with any maximum luminance level in-between SDR and HDR. The primary goal of this HDR workflow is to provide direct HDR backward compatible services i.e. services which associated streams are directly compatible with HDR Consumer Electronics devices. This workflow is based on technologies and standards that facilitate an open approach.

It includes a single-layer HDR encoding-decoding, and uses static and dynamic metadata:

- Mastering Display Colour Volume (MDCV) standardized in AVC [4], HEVC [5] and SMPTE ST 2086 [7] specifications; and
- SL-HDR Information (SL-HDRI) based on both SMPTE ST 2094-20 [i.6] and SMPTE ST 2094-30 [i.7] specifications.

Single-layer encoding/decoding requires only one encoder instance at HDR encoding side, and one decoder instance at player/display side. It supports the real-time workflow requirements of broadcast applications.

The elements specifically addressed in the present document are related to the HDR/SDR reconstruction process and the associated dynamic metadata format.

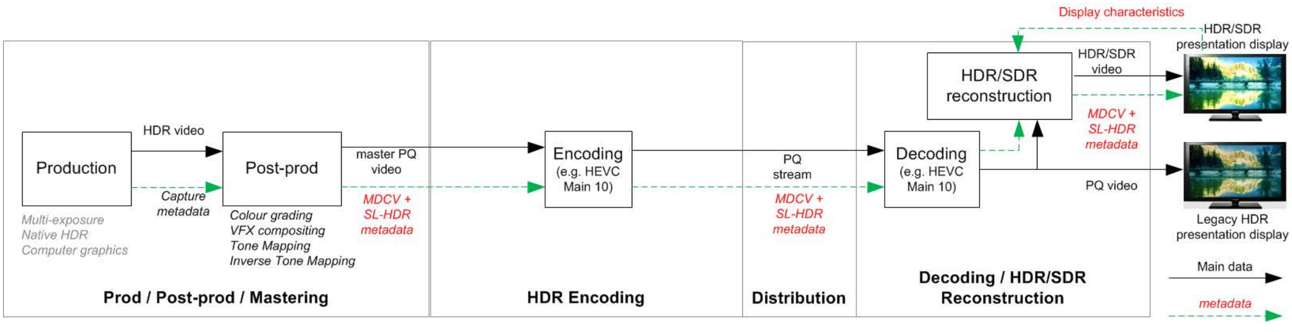

Figure 1: Example of an HDR end-to-end system

5 HDR system architecture

The block diagram in Figure 2 depicts in more detail the HDR decomposition and reconstruction processes. The centre block included in dash-red box corresponds to the distribution encoding and decoding stages (e.g. based on HEVC video coding specifications). The left and right grey-coloured boxes respectively enable format adaptation to the input video signal of the HDR system and to the targeted system (e.g. a STB, a connected TV, etc.) connected with the HDR system. The black solid line boxes show the HDR specific processing. The additional HDR dynamic metadata are transmitted on distribution networks typically by way of the SEI messaging mechanism. The present document relates to both the HDR-to-HDR/SDR signal reconstruction process and the HDR metadata format. The core component of the HDR decomposition stage is the HDR-to-SDR decomposition that generates an SDR video from the HDR signal.

Optionally in the IRD, a block of gamut mapping may be used when the output HDR/SDR picture is represented in a colour space or colour gamut different from the one of the connected display. The parameters of the optional gamut mapping and their impact on the rendering may be controlled during the post-production stage.

Optionally in the IRD, a block of HDR-to-HDR signal reconstruction may be used as a display adaptation process. The dynamic range output of the display adaptation process may be less and may be more than the dynamic range of the HDR signal input to the HDR-to-SDR signal decomposition process.

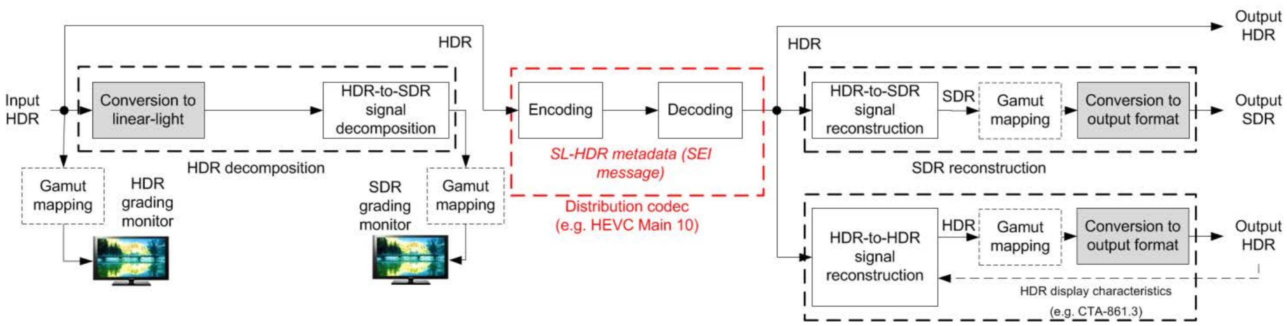

Figure 2: HDR system architecture overview

6 Dynamic metadata format for HDR-to-HDR/SDR adaptation

Clause 6 of ETSI TS 103 433-1 [1] specifies the dynamic metadata format for signal reconstruction. In the present document, the dynamic metadata allow conversion of the HDR signal to any maximum luminance between SDR (100 cd/m²) and a value higher than the original maximum luminance, guided by this dynamic metadata. A recommendation for the maximum luminance boundary can be found in Annex H.

Clause 6 of ETSI TS 103 433-1 [1] shall apply to the present document, taking into account the restrictions on allowed values and the setting of specific values as specified in Annex A of the present document, as they change clause 6 through the mapping specified in Annex A of ETSI TS 103 433-1 [1] and taking the following exceptions into account.

SL-HDR2 core metadata related clauses:

- Clause 6.2.2 "Signal reconstruction information" of ETSI TS 103 433-1 [1]
  In the present document, the reconstructed signal can be an SDR signal, in case the presentation display adaptation of clause 7.3 is not used in clause 7.2, or an HDR signal if the presentation display adaptation is used.

- Clause 6.3.2.1 "Introduction" of [1]
  In the present document, signal_reconstruction_info contains the dynamic metadata that, when combined with the associated HDR picture, enables reconstruction of an SDR picture (as described in clause 7), in case the presentation display adaptation of clause 7.3 is not used in clause 7.2, or an HDR picture if the presentation display adaptation is used.

- The note in clause 6.3.3.4 "hdrDisplayMaxLuminance - HDR mastering display maximum luminance" of [1] does not apply to the present document.

- Clause 6.3.4.1 "Introduction" of [1]
  In the present document, the HDR picture and not the SDR picture is intended to be encoded and transmitted on distribution networks.

- Clause 6.3.5.1, 6.3.6.1, 6.3.7.1, and 6.3.8.1 "Introduction" of [1]
  In the present document, those variables are used in the HDR-to-HDR/SDR signal reconstruction process specified in clause 7.

Gamut Mapping related clauses

- Clause 6.3.2.9 "gamutMappingMode" of [1]
  In the present document, the value of **gamutMappingMode** shall be in the range of 0 to 1, inclusive, and 4 to 5, inclusive, and 64 to 127, inclusive, see Table 2.

Table 2: Gamut mapping mode

Value of gamutMappingMode	Gamut mapping mode
0	Implementation dependent method
1	Explicit parameters (see clause 6.3.9 of [1])
2	Reserved for ETSI TS 103 433-1 [1]
3	Reserved for ETSI TS 103 433-1 [1]
4	Preset #3: P3D65 to BT.709 gamut (see Table 3)
5	Preset #4: BT.2020 to BT.709 gamut (see Table 4)
6 - 63	Reserved for future use
64 - 127	Unspecified
128 - 255	Reserved for future use

Preset #3 and preset #4 shall only apply to the present document. In the present document, Table 3 and Table 4 respectively provide the predetermined values of the variables that respectively correspond to a gamut mapping (gamut compression) from P3D65 gamut represented with BT.2020 primaries to BT.709 gamut represented with BT.709 primaries (preset #3) or from BT.2020 gamut represented with BT.2020 primaries to BT.709 gamut represented with BT.709 primaries (preset #4).

Table 3: Preset #3: P3D65 gamut with BT.2020 primaries to BT.709 gamut

Gamut mapping variable	Variable value
satMappingMode	2
sat1SegRatio[c]	$\{\frac{6}{8}; \frac{7}{8}; \frac{7}{8}; \frac{7}{8}; \frac{7}{8}; \frac{7}{8}\}$
sat2SegRatioWCG[c]	$\{\frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}\}$
sat2SegRatioSCG[c]	$\{\frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}\}$
lightnessMappingMode	2
croppingModeSCG	2
cmCroppedLuminanceMappingEnabledFlag	1
hueAdjMode	1
hueAlignCorrectionPresentFlag	1
hueAlignCorrection[c]	{4; 5; 4; 4; 5; 4}
chromAdjPresentFlag	0

Table 4: Preset #4: BT.2020 gamut to BT.709 gamut

Gamut mapping variable	Variable value
satMappingMode	2
sat1SegRatio[c]	$\left\{\frac{7}{8}; \frac{7}{8}; \frac{7}{8}; \frac{6}{8}; \frac{7}{8}; \frac{7}{8}\right\}$
sat2SegRatioWCG[c]	$\left\{\frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}\right\}$
sat2SegRatioSCG[c]	$\left\{\frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}; \frac{35}{64}\right\}$
lightnessMappingMode	2
croppingModeSCG	2
cmCroppedLuminanceMappingEnabledFlag	1
hueAdjMode	2
hueGlobalPreservationRatio	4
hueAlignCorrectionPresentFlag	1
hueAlignCorrection[c]	{4; 5; 4; 4; 5; 4}
chromAdjPresentFlag	0

7 HDR-to-HDR/SDR signal reconstruction process

7.1 Input streams

The input stream is composed of a decoded PQ, see SMPTE ST 2084 [6], HDR video stream and associated dynamic metadata that are combined to reconstruct an HDR or an SDR video signal. The dynamic metadata can be conveyed thanks to two mutually exclusive modes: a parameter-based mode (**payloadMode** 0) and a table-based mode (**payloadMode** 1). Concerning ITU-T or ISO/IEC based video codecs, both payload carriage modes are carried by the SL-HDR Information SEI message specified in [1], which message is a User Data Registered SEI message. The HDR-to-HDR/SDR reconstruction process is specified in clause 7.2. The metadata recomputation necessary for the HDR-to-HDR reconstruction process is specified in clause 7.3. These processes employ syntax element specified in clause 6.2 of [1] and retrieved from parsed and mapped (see clause A.2.3 of [1]) dynamic metadata streams. Semantics attached to the syntax elements is provided in clause 6.3 of [1].

7.2 Reconstruction process of an SDR or HDR stream

7.2.1 Introduction

Clause 7.2 specifies the reconstruction process enabling the generation of an SDR picture from an HDR picture with associated dynamic metadata. In this case, the associated dynamic metadata are used unchanged.

Clause 7.2 also specifies the reconstruction process enabling the generation of an HDR picture adapted for the maximum luminance, L_{pdisp}, of the presentation display from an HDR picture with associated dynamic metadata. This case is called display adaptation. In this case, the associated dynamic metadata are recomputed first as specified in clause 7.3 before they are used as specified in the next clauses of clause 7.2. The value of L_{pdisp} can be anywhere in between SDR, 100 cd/m², and a value higher than the maximum luminance of the HDR grading monitor used to grade the input HDR picture (source picture). See Annex H for the recommended range of values of L_{pdisp} to perform display adaptation with. The maximum supported HDR grading monitor luminance is 10 000 cd/m².

This process is defined for a full range PQ HDR picture signal, see SMPTE ST 2084 [6]. For an HDR picture defined as narrow-range signal, an (unspecified) conversion to full range process shall be applied first (e.g. as specified in Annex A of SMPTE ST 2084 [6]). The specified process assumes that the HDR picture signal is represented with a bit depth of 10-bit per component.

The process depicted in Figure 3 can be summarized as follows:

- From the input metadata conveyed in either **payloadMode** 0 or 1, a luma-related look-up table, $lutMapY$, is derived (see clause 7.2.3.1).
- Similarly, from the input metadata conveyed in either **payloadMode** 0 or 1, a colour correction look-up table, $lutCC$, is derived (see clause 7.2.3.2).
- The next step, described in clause 7.2.4, consists of applying the HDR-to-HDR/SDR reconstruction from the input HDR picture (source picture), the derived luma-related look-up table and colour correction look-up table. This process produces an output linear-light HDR or SDR picture.
- An optional gamut mapping can be applied when the colour gamut and/or colour space of the output HDR/SDR picture (as specified by the variable **sdrPicColourSpace**) and the one of the connected display are different. If the optional gamut mapping parameters are present in the dynamic metadata, they may be used for the optional gamut mapping, see clause A.2.2.3 and clause A.2.2.4 of [1].

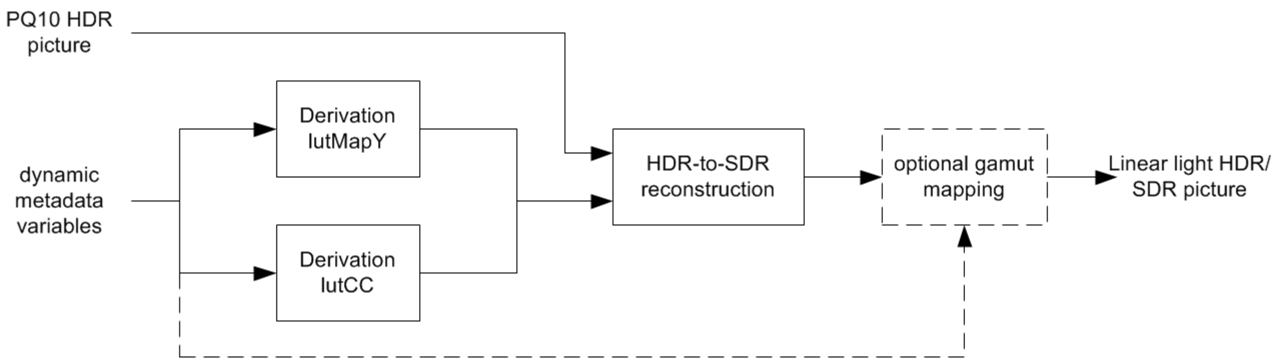

Figure 3: Overview of the SDR reconstruction process.

In the next clauses of clause 7.2, the variables $picWidth$, $picHeight$ and $maxSampleVal$ are defined as follows:

- $picWidth$ and $picHeight$ are the width and height, respectively, of the HDR picture (e.g. as specified by the syntax elements **pic_width_in_luma_samples** and **pic_height_in_luma_samples** in the HEVC specification [5]);
- $maxSampleVal$ is equal to 2^{10} i.e. 1 024.

When reconstructing an SDR picture, 100 cd/m² shall be used, in the next clauses of clause 7.2 for the value of the variable L_{pdisp}, the maximum luminance of the presentation display and the metadata values shall be used unchanged.

When reconstructing an HDR picture with a different maximum luminance L_{pdisp} than 100 cd/m², the metadata values have to be recomputed first, as specified in clause 7.3, before they can be used in the next clauses of clause 7.2. The value of L_{pdisp} can in this case be anywhere in between SDR, 100 cd/m², and the maximum luminance **hdrDisplayMaxLuminance** (see clause 6.2.3 of [1]) of the HDR grading monitor used to grade the input HDR picture (source picture).

7.2.2 Selecting a reconstruction mode

Clause 7.2.3 describes the processing steps to construct luminance mapping and colour correction tables that are used as inputs to the SDR stream reconstruction process. The SDR reconstruction process operates on look-up tables reconstructed from variables (**payloadMode** 0) specified in clauses 7.2.3.1 and 7.2.3.2 or derived from coded look-up tables (**payloadMode** 1) specified in clauses 7.2.3.3 and 7.2.3.4. The SDR picture reconstruction process specified in clause 7.2.4 is common to both modes (**payloadMode** 0 and 1).

7.2.3 Luminance mapping and colour correction tables construction

7.2.3.1 Luminance mapping table construction from variables (payloadMode 0)

7.2.3.1.1 Introduction

The luminance mapping table construction for **payloadMode** 0 derives a 1D look-up table $lutMapY$ from the luminance mapping variables as described in clause 6.2.5 of [1].

This process takes as inputs:

- the HDR picture characteristics variable **hdrDisplayMaxLuminance**;
- the SDR picture characteristics variable **sdrDisplayMaxLuminance**; and
- the luminance mapping variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[i] and **tmOutputFineTuningY**[i].

The process generates as output:

- the luminance mapping look-up table $lutMapY$ of $maxSampleVal$ entries.

7.2.3.1.2 Overview of the computation of lutMapY

The look-up table $lutMapY[L]$, for luma values $L = 0..(maxSampleVal - 1)$, implements a tone mapping function. The tone mapping process is shown in Figure 4.

For any L in 0. ($maxSampleVal$ - 1), the $lutMapY[L]$ is derived by applying the following steps:

- L is converted from the PQ domain to the perceptually uniform domain (uniform lightness), based on the HDR mastering display maximum luminance, represented by **hdrDisplayMaxLuminance**, by invoking clause 7.2.3.1.3, with L as input and Y_{pus} as output.
- The black and white level offsets are applied by invoking clause 7.2.3.1.4, with Y_{pus}, the (possibly recomputed) variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** as inputs, and Y_{bw} as output.
- The tone mapping curve is applied by invoking clause 7.2.3.1.5, with Y_{bw}, the (possibly recomputed) variables **shadowGain**, **highlightGain**, **midToneWidthAdjFactor** and **hdrDisplayMaxLuminance** as inputs, and Y_{adj} as output.
- The fine tuning process is applied by invoking clause 7.2.3.1.6, with Y_{adj}, the (possibly recomputed) variables **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[i] and **tmOutputFineTuningY**[i], for i=0..(**tmOutputFineTuningNumVal** - 1) as inputs and Y_{ft} as output.
- The signal Y_{ft} is processed through a gain limiter by invoking clause 7.2.3.1.7, with Y_{ft} and Y_{pus} as inputs, and Y_{glim} as output. A choice is made between limiting Y_{ft} and passing it on unchanged, based on the value of the (possibly recomputed) variable **tmInputSignalBlackLevelOffset**.
- The signal Y_{glim} is converted from the perceptually uniform domain to the linear-light domain based on the maximum luminance L_{pdisp} of the presentation display, by invoking clause 7.2.3.1.8, with Y_{glim} and L_{pdisp} as inputs, and Y_{ll} as output. If L_{pdisp} is not equal to 100 cd/m², the metadata values have to be recomputed first as specified in clause 7.3.
- The final output $lutMapY[L]$ is derived from the variable Y_{ll} by invoking clause 7.2.3.1.9.

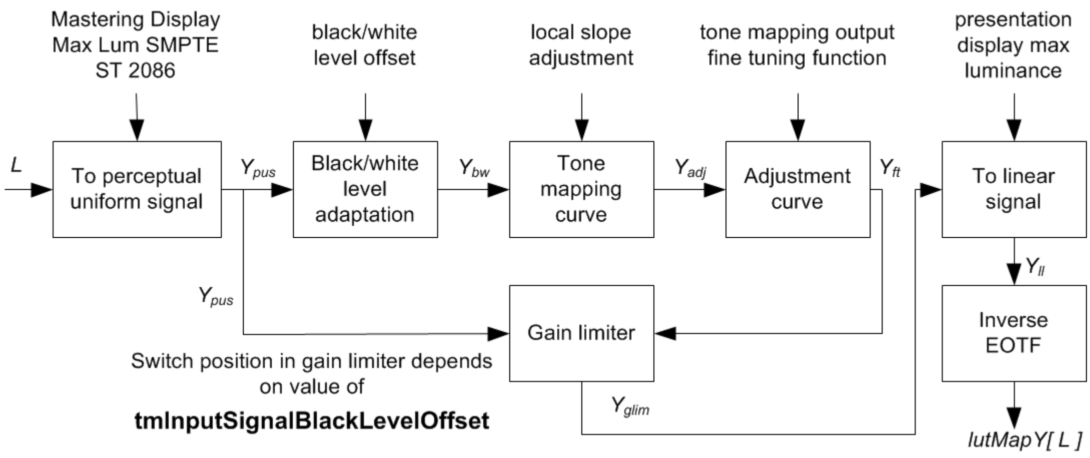

Figure 4: Tone mapping process

The blocks shown in Figure 4 are specified in detail in the clauses 7.2.3.1.3 to 7.2.3.1.9.

7.2.3.1.3 Block "To perceptual uniform signal"

This process takes as input:

- the PQ luma value L; and
- the variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]).

The process generates as output:

- the perceptual uniform value Y_{pus}.

In the first step, L, which is a SMPTE ST 2084 [6] compatible PQ signal, shall be converted to normalized linear light using the PQ EOTF function, $PQ_{EOTF}(N)$, as specified by equation 4.1 in [6] to yield the linear-light signal Y_2.

$$Y_2 = \frac{10\,000}{L_{HDR}} \times PQ_{EOTF}\left(\frac{L}{maxSampleVal - 1}\right) \quad (1)$$

In the second step, the inverse EOTF, $v(x;y)$, shall be performed on $x = Y_2$, where $v(x;y)$ is the perceptually uniform colour component, when applied to the linear components, x, normalized to 0..1, where 1 corresponds to the maximum display luminance of the HDR mastering display **hdrDisplayMaxLuminance**, and using γ = 2,4, in order to get the perceptually uniform signal Y_{pus}., as specified by equations (2), (3) and (4),

$$v(x;y) = \frac{\log_{10}\left(1 + (\rho(y) - 1) \times x^{\frac{1}{2,4}}\right)}{\log_{10}(\rho(y))} \quad (2)$$

$$\rho(y) = 1 + (33 - 1) \times \left(\frac{y}{10000}\right)^{\frac{1}{2,4}} \quad (3)$$

$$Y_{pus} = v(Y_2; L_{HDR}) \quad (4)$$

where:

- L_{HDR} shall be the HDR mastering display maximum luminance **hdrDisplayMaxLuminance**.

7.2.3.1.4 Block "Black/white level adaptation"

This process takes as inputs:

- the perceptual uniform value, Y_{pus} ; and
- the (possibly recomputed) variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset**.

The process generates as output:

- the stretched value Y_{bw}.

In this block, the input signal Y_{adj} shall be adapted by the black and white stretch in order to derive the output signal Y_{bw}, as specified by equation (5) up to and including (7),

$$Y_{bw} = \frac{Y_{pus} - blo}{1 - wlo - blo} \quad (5)$$

$$wlo = \frac{255 \times \mathbf{tmInputSignalWhiteLevelOffset}}{510} \quad (6)$$

$$blo = \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset}}{2040} \quad (7)$$

The variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** shall be taken from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]). In case display adaptation is performed, these parameters shall be recomputed as specified in clause 7.3.3 before being used in equations (6)and (7).

7.2.3.1.5 Block "Tone mapping curve"

This process takes as inputs:

- the black/white adapted value Y_{bw};
- the (possibly recomputed) variables **shadowGain**, **highlightGain**, **midToneWidthAdjFactor** (clause 6.2.5 of [1]);
- the variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]); and
- the maximum luminance L_{pdisp} of the presentation display, see clause 7.2.1.

The process generates as output:

- the tone-mapped value, in linear-light domain, Y_{adj}.

In this block, the input signal Y_{bw} shall be converted by a tone mapping curve to the output signal Y_{adj} according to equation (8).

$$Y_{adj} = TMO(Y_{bw}) \quad (8)$$

The tone mapping curve TMO shall be built from (possibly recomputed) variables **shadowGain** (= base gain), **midToneWidthAdjFactor** (= parabola part), and **highlightGain** (= differential gain at the end), as well as **hdrDisplayMaxLuminance** and L_{pdisp}, as specified by equations (9) up to and including equation (17). The basics of the curve for TMO are explained below and an example is shown in Figure 5.

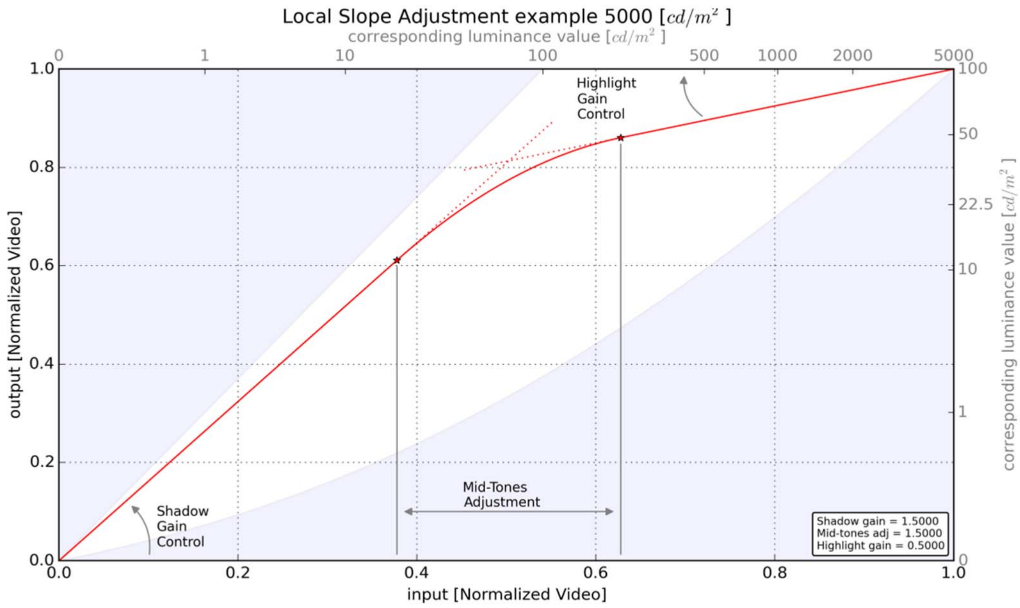

Figure 5: Tone mapping curve shape example

The tone mapping curve is applied in a perceptually-uniform domain and is a piece-wise curve constructed out of three parts, which are specified by three shape parameters.

Parameter #1 is the base gain. This determines the brightness for most of the image except the highlights. It shall be determined by the variable **shadowGain** in the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]).

Parameter #2 is the highlight differential gain. This determines how much of the details in highlights is preserved, at the cost of the peak brightness. It shall be determined by the variable **highlightGain** in the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]).

Lines #1 and #2 intersect, and together they form an abrupt change in gain. If this is not desired then a parabola segment can be inserted, and this is symmetrical with respect to the original intersection point of the 2 lines.

Parameter #3 is the width of the parabolic segment. It shall be determined by the variable **midToneWidthAdjFactor** in the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]).

Equation (9) up to and including equation (17) specify the calculations in order to arrive at the piece-wise constructed curve.

$$TMO(x) = \begin{cases} SGC \times x, & 0 \leq x \leq x_{SGC} \\ ax^2 + bx + c, & x_{SGC} < x < x_{HGC} \\ HGC \times x + 1 - HGC, & x_{HGC} \leq x \leq 1 \end{cases} \quad (9)$$

$$a = \begin{cases} 0, & para = 0 \\ -0{,}5 \times \frac{SGC-HGC}{para}, & otherwise \end{cases}$$
$$b = \begin{cases} 0, & para = 0 \\ \frac{1-HGC}{para} + \frac{SGC+HGC}{2}, & otherwise \end{cases} \quad (10)$$
$$c = \begin{cases} 0, & para = 0 \\ -\frac{\left((SGC-HGC)\times para-2(1-HGC)\right)^2}{8\times(SGC-HGC)\times para}, & otherwise \end{cases}$$

$$x_{SGC} = \frac{1-HGC}{SGC-HGC} - \frac{para}{2}$$
$$x_{HGC} = \frac{1-HGC}{SGC-HGC} + \frac{para}{2} \quad (11)$$

$$exposure = \frac{\textbf{shadowGain}}{4} + 0{,}5 \quad (12)$$

$$expgain = v\left(\frac{L_{HDR}}{L_{pdisp}}; L_{pdisp}\right) \quad (13)$$

$$L_{HDR} = \textbf{hdrDisplayMaxLuminance} \quad (14)$$

$$SGC = expgain \times exposure \quad (15)$$

$$HGC = \frac{\textbf{highlightGain}}{4} \quad (16)$$

$$para = \frac{\textbf{midToneWidthAdjFactor}}{2} \quad (17)$$

If L_{pdisp} is not equal to 100 cd/m², the metadata values have to be recomputed first as specified in clause 7.3.

The value of **hdrDisplayMaxLuminance**, as used in equation (14), shall be taken from the metadata structure hdr_characteristics( ) as specified in clause 6.3.3.4 of [1].

7.2.3.1.6 Block "Adjustment curve"

This process takes as inputs:

- the tone-mapped value Y_{adj}; and
- the (possibly recomputed) variables **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[i] and **tmOutputFineTuningY**[i], for i=0..(**tmOutputFineTuningNumVal** - 1) (clause 6.2.5 of [1]).

The process generates as output:

- the corrected value Y_{ft}.

In this block, the input signal Y_{adj} shall be corrected by the *ToneMappingOutputFineTuningFunction* function f_{ftlum}( ), as specified by equation (18).

The *ToneMappingOutputFineTuningFunction* function f_{ftlum}( ), is a piecewise linear function; see clause 7.3 of [1] for the computation of f_{ftlum}( ) from the list of points.

The list of points explicitly defining the *ToneMappingOutputFineTuningFunction* function shall be the pairs **tmOutputFineTuningX**[i], **tmOutputFineTuningY**[i], in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 of [1], possibly extended with a point at the start and/or at the end, as specified in clause 6.3.5.9 of [1] and recomputed as specified in clause 7.3 in case L_{pdisp} is greater than 100 cd/m².

$$Y_{ft} = \begin{cases} f_{ftlum}(Y_{adj}), & 0 \le Y_{adj} \le 1 \\ Y_{adj}, & otherwise \end{cases} \quad (18)$$

An example fine tuning curve is shown in Figure 6.

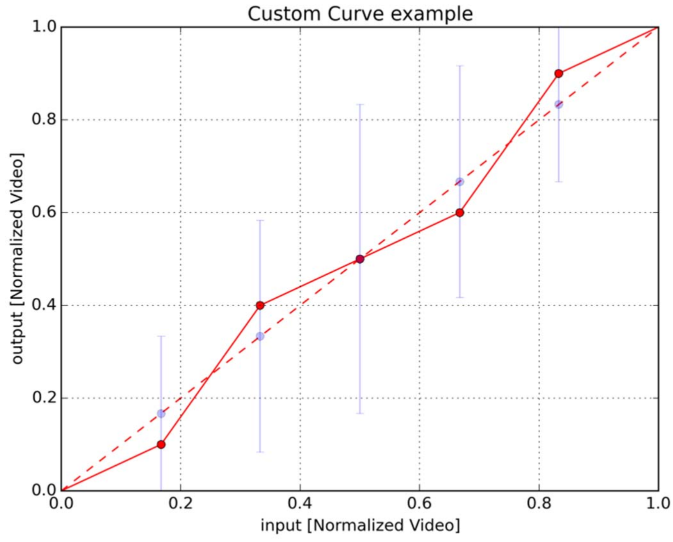

Figure 6: Example fine-tuning curve

7.2.3.1.7 Block "Gain limiter"

This process takes as inputs:

- the value Y_{ft} from clause 7.2.3.1.6;
- the value Y_{pus} from clause 7.2.3.1.3;
- the (possibly recomputed) variable **tmInputSignalBlackLevelOffset** in the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]); and
- the variable **hdrDisplayMaxLuminance** in the structure hdr_characteristics( ) of the reconstruction metadata (clause 6.2.3 of [1]).

The process generates as output:

- the value Y_{glim}.

In this block, a choice is made between limiting Y_{ft} and passing it on unchanged, based on the value of the (possibly recomputed) variable **tmInputSignalBlackLevelOffset**.

When the value of the variable **tmInputSignalBlackLevelOffset** is equal to 0, the output Y_{glim} of this block shall be the value Y_{ft}.

When the value of the variable **tmInputSignalBlackLevelOffset** is not equal to 0, the value Y_{ft} shall be corrected for minimum gain based on the ratio of the maximum luminance of the HDR mastering display, L_{HDR}, which is equal to the variable **hdrDisplayMaxLuminance** in the structure hdr_characteristics( ) of the reconstruction metadata (clause 6.2.3 of [1]), and the maximum luminance of the SDR mastering display L_{SDR} of 100 cd/m^2, using Y_{pus} from clause 7.2.3.1.3 as specified in equations (19) and (20),

$$Y_{glim} = Max(Y_{ft}\,;\,Y_{pus} \times g) \quad (19)$$

$$g = v(0{,}1 \div L_{SDR}; L_{SDR}) \div v(1 \div L_{HDR}; L_{HDR}) \quad (20)$$

with the inverse EOTF, $v(x, y)$, taken from equations (2) and (3).

7.2.3.1.8 Block "To linear signal"

This process takes as inputs:

- the gain limited value Y_{glim}; and
- the maximum luminance L_{pdisp} of the presentation display, see clause 7.2.1.

The process generates as output:

- the linear-light value Y_{ll}.

In this block the computation of the value Y_{ll}, the input signal Y_{glim} shall be converted from the perceptually uniform domain to the linear-light domain output value Y_{ll}, using the EOTF, $v_{inv}(x;y)$ as specified in equations (21) and (22) and shall be based on the maximum luminance L_{pdisp} of the presentation display, see clause 7.2.1.

$$v_{inv}(x;y) = \left(\frac{\rho(y)^x - 1}{\rho(y) - 1}\right)^{2,4} \quad (21)$$

$$Y_{ll} = v_{inv}(Y_{glim}; L_{pdisp}) \quad (22)$$

7.2.3.1.9 Block "Inverse EOTF"

This process takes as inputs:

- the linear-light value Y_{ll} ; and
- the maximum luminance L_{pdisp} of the presentation display, see clause 7.2.1.

The process generates as output:

- the value $lutMapY[\ L\ ]$.

In this block, the inverse PQ EOTF is applied to the value Y_{ll} in order to compute the value of $lutMapY[\ L\ ]$ as specified in equation (23):

$$lutMapY[\ L\ ] = invPQ(Y_{ll} \times L_{pdisp}) \quad (23)$$

where:

- $invPQ(C)$ is the inverse of the PQ EOTF as specified by equations 5.1 and 5.2 of [6].

7.2.3.2 Colour correction table construction from parameter-based mode (payloadMode 0)

The colour correction table construction for payload mode 0 derives a 1D look-up table $lutCC$.

This process takes as inputs:

- the HDR picture mastering display maximum luminance **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]);
- the SDR picture mastering display maximum luminance **sdrDisplayMaxLuminance** (clause 6.2.4 of [1]);
- the maximum luminance L_{pdisp} of the presentation display, see clause 7.2.1.; and
- the colour correction adjustment variables **saturationGainNumval**, **saturationGainX**[i] and **saturationGainY**[i] (clause 6.2.6 of [1]).

The process generates as output:

- the colour correction look-up table $lutCC$ of $maxSampleVal$ entries.

The value of $lutCC[\ 0\ ]$ shall be derived as specified in equation (24):

$$lutCC[0] = 0{,}125 \quad (24)$$

For each luma value Y in 1..($maxSampleVal$ - 1), $lutCC$[Y] shall be derived as specified in equation (25):

$$lutCC[Y] = Min\left(lutCC[0]\ ;\ \frac{1+c(L_{HDR};L_{SDR};L_{pdisp})\times {Y_n}^{2,4}}{Y_n\times Max\left(R_{sgf}\div 255\ ;\ R_{sgf}\times g(Y_n)\right)}\times\frac{1}{maxSampleVal-1}\right) \quad (25)$$

where:

- $Y_n = \frac{Y}{maxSampleVal-1}$
- $g(Y_n) = f_{sgf}(Y_n)\ \times\ modFactor +\ (1 - modFactor) \div R_{sgf}$;

  where:

  - $modFactor = 0$, if the L_{pdisp} equals L_{HDR};
  - $modFactor = 1$, if the L_{pdisp} equals L_{SDR}; and
  - $modFactor = c(L_{HDR}; L_{SDR}; L_{pdisp})$.

- The saturation gain function $f_{sgf}(\ )$ is derived from the piece-wise linear pivot points defined by the variables **saturationGainX**[i] and **saturationGainY**[i], for i=0..(**saturationGainNumVal** - 1), see clause 7.3 of [1]. When **saturationGainNumVal** is equal to 0, $f_{sgf}(\ ) =\ 1 \div R_{sgf}$.
- R_{sgf} = 2 in the present document.

The colour correction function $c(L_{HDR}; L_{SDR}; L_{pdisp})$ shall be derived as specified in equation (26):

$$c(L_{HDR}; L_{SDR}; L_{pdisp}) = 1 - \frac{invPQ(L_{pdisp}) - invPQ(L_{SDR})}{invPQ(L_{HDR}) - invPQ(L_{SDR})} \quad (26)$$

where:

- L_{HDR} shall be the HDR picture mastering display max luminance **hdrDisplayMaxLuminance**;
- L_{SDR} shall be the SDR picture mastering display max luminance **sdrDisplayMaxLuminance**, which shall be taken as 100 cd/m²;
- L_{pdisp} shall be the maximum luminance of the presentation display, see clause 7.2.1; and
- $invPQ(C)$ shall be the inverse of the PQ EOTF as specified by equations 5.1 and 5.2 of [6].

7.2.3.3 Luminance mapping table retrieval (payloadMode 1)

This process derives, for payload mode 1, a 1D look-up table $lutMapY$ from the luminance mapping variables specified in clause 6.2.7 of [1].

This process takes as inputs:

- the luminance mapping table variables **luminanceMappingNumVal**, **luminanceMappingX**[i] and **luminanceMappingY**[i];

The process generates as output:

- the luminance mapping table $lutMapY$ of $maxSampleVal$ entries.

The variables **luminanceMappingX**[i] and **luminanceMappingY**[i], for i=0..(**luminanceMappingNumVal** - 1), shall correspond to piece-wise linear pivot points representative of the curve $f_{luma}(\ )$ used to derive the look-up table $lutMapY$. See clause 7.3 of [1] for the computation of $f_{luma}(\ )$ from the list of points.

For any Y in 0. ($maxSampleVal$ - 1), $lutMapY$[Y] shall be derived as specified in equation (27):

$$lutMapY[\ Y\ ] = f_{luma}\left(\frac{Y}{maxSampleVal-1}\right) \quad (27)$$

7.2.3.4 Colour correction table retrieval (payloadMode 1)

The process derives, for payload mode 1, a 1D look-up table *lutCC* from the colour correction table as described in clause 6.2.8 of [1].

This process takes as inputs:

- the colour correction table variables **colourCorrectionNumVal**, **colourCorrectionX**[i] and **colourCorrectionY**[i].

The process generates as output:

- the colour correction table *lutCC* of *maxSampleVal* entries.

The variables **colourCorrectionX**[i] and **colourCorrectionY**[i], for i=0..(**colourCorrectionNumVal** - 1), shall correspond to piece-wise linear pivot points representative of the curve $f_{chroma}()$ used to derive the look-up table *lutCC*. See clause 7.3 of [1] for the computation of $f_{chroma}()$ from the list of points.

- For any *Y* in 0..(*maxSampleVal* - 1), *lutCC*[*Y*] shall be derived as specified in equation (28):

$$lutCC[\,Y\,] = f_{chroma}\left(\frac{Y}{maxSampleVal - 1}\right) \quad (28)$$

7.2.4 HDR/SDR picture reconstruction from look-up tables and HDR picture

The HDR/SDR reconstruction process generates the reconstructed HDR/SDR picture from the decoded HDR picture and the luminance mapping and colour correction tables.

This process takes as inputs:

- a PQ HDR picture made of two-dimensional arrays HDR_Y, HDR_{Cb}, HDR_{Cr} of width *picWidth* and height *picHeight*, after applying on the decoded picture an (unspecified) upsampling conversion process to the 4:4:4 colour sampling format, an (unspecified) samples conversion to full range and possibly an (unspecified) bit depth conversion to 10 bits per component, therefore normalized in the interval 0..1 023;
- the luminance mapping table *lutMapY* of *maxSampleVal* entries;
- the colour correction table *lutCC* of *maxSampleVal* entries;
- the maximum luminance of the presentation display L_{pdisp};
- the four matrix coefficients variables **matrixCoefficient**[i] (clause 6.3.2.6 of [1]);
- the two luma injection variables **chromaToLumaInjection**[i] (clause 6.3.2.7 of [1]); and
- the three "k" coefficients variables **kCoefficient**[i] (clause 6.3.2.8 [1]).

The process generates as output:

- the linear light 4:4:4 picture made of two-dimensional arrays HDR_R, HDR_G, HDR_B of width *picWidth* and height *picHeight*, with pixel values in the range [0..L_{pdisp}].

NOTE 1: In case $L_{pdisp} = 100\ \mathrm{cd/m^2}$, the picture in the two-dimensional arrays HDR_R, HDR_G, HDR_B can be converted to an SDR picture by using gamma correction. For $L_{pdisp} > 100\ \mathrm{cd/m^2}$, metadata recomputation for display adaptation is used as specified in clause 7.3.

NOTE 2: Due to the restrictions in Annex A, **chromaToLumaInjection**[i] = 0 and **kCoefficient**[i] = 0 for all values of i. The specification below is therefore a simplified version of the one in clause 7.2.4 of [1] adapted for use in HDR-to-HDR/SDR conversion.

The HDR/SDR reconstruction process shall perform the following successive steps for each pixel x = 0..(*picWidth - 1*), y = 0..(*picHeight - 1*).

- The variables U_{post1} and V_{post1} shall be derived as specified in equation (29):

$$\begin{cases} U_{post1} = HDR_{cb}[x][y] - midSampleVal \\ V_{post1} = HDR_{cr}[x][y] - midSampleVal \end{cases} \quad (29)$$

where: *midSampleVal* is equal to *maxSampleVal* / 2 = 512.

- The variable Y_{post1} shall be derived as specified in equation (30):

$$Y_{post1} = HDR_y[x][y] \quad (30)$$

- The variable Y_{post2} shall be derived as specified in equation (31):

$$Y_{post2} = Clip3(0; maxSampleVal - 1; Y_{post1}) \quad (31)$$

- U_{post2} and V_{post2} shall be derived from U_{post1} and V_{post1} as specified in equation (32):

$$\begin{cases} U_{post2} = lutCC[Y_{post2}] \times U_{post1} \times maxCoeff \div m_3 \\ V_{post2} = lutCC[Y_{post2}] \times V_{post1} \times maxCoeff \div m_3 \end{cases} \quad (32)$$

  where:

  - $maxCoeff = 1{,}8814$ when **hdrPicColourSpace** is equal to 1;
  - $maxCoeff = 1{,}8556$ when **hdrPicColourSpace** is equal to 0;
  - $m_3 =$ **matrixCoefficient**[3].

- The variables R_1, G_1, B_1 shall be derived as specified in equation (33):

$$\begin{bmatrix} R_1 \\ G_1 \\ B_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & m_0 \\ 1 & m_1 & m_2 \\ 1 & m_3 & 0 \end{bmatrix} \times \begin{bmatrix} 1 \\ U_{post2} \\ V_{post2} \end{bmatrix} \quad (33)$$

  where $m_i =$ **matrixCoefficient**[i] and $i \in [\![0, 3]\!]$.

- The variables R_2, G_2, B_2 shall be derived from R_1, G_1, B_1 as specified in equation (34):

$$\begin{cases} R_2 = lutMapY[Y_{post2}] \times R_1) \\ G_2 = lutMapY[Y_{post2}] \times G_1) \\ B_2 = lutMapY[Y_{post2}] \times B_1) \end{cases} \quad (34)$$

- The output samples $HDR_R[x][y]$, $HDR_G[x][y]$, $HDR_B[x][y]$ shall be derived from R_2, G_2, B_2 as specified in equation (35):

$$\begin{cases} HDR_R[x][y] = 10\,000 \times PQ_{EOTF}(R_2) \\ HDR_G[x][y] = 10\,000 \times PQ_{EOTF}(G_2) \\ HDR_B[x][y] = 10\,000 \times PQ_{EOTF}(B_2) \end{cases} \quad (35)$$

  where:

  - HDR_R, HDR_G and HDR_B are in the linear light domain and in the range [0..L_{pdisp}];
  - L_{pdisp} is the maximum luminance of the presentation display, see clause 7.2.1;
  - $PQ_{EOTF}(N)$ is the PQ EOTF function as specified by equation 4.1 in [6].

7.3 Metadata recomputation for presentation display adaptation

7.3.1 Introduction

Clause 7.2 specifies the reconstruction process enabling the generation of an SDR picture, a picture with a maximum luminance of 100 cd/m², from an HDR picture with associated dynamic metadata. Clause 7.2 also specifies the generation of an HDR picture adapted for the maximum luminance, L_{pdisp}, of the presentation display in case L_{pdisp} is anywhere in between 100 cd/m² and a value higher than the maximum luminance of the HDR grading monitor. See Annex H for the recommended range of values of L_{pdisp} to perform display adaptation with.

For the adapted HDR picture generation, or display adaptation, certain metadata needs to be recomputed before it can be used in clause 7.2. Clause 7.3 specifies the recomputation of that metadata. In particular, the metadata variables that have to be recomputed are:

- **tmwSignalWhiteLevelOffset;**
- **tmInputSignalBlackLevelOffset;**
- **shadowGain;**
- **highlightGain;**
- **midToneWidthAdjFactor;**
- **tmOutputFineTuningX[i]; and**
- **tmOutputFineTuningY[i].**

Furthermore, the value of $modFactor$ needs to be computed.

These metadata variables and $modFactor$ are recomputed based on the maximum luminance of the presentation display L_{pdisp}, and the maximum luminance of the HDR grading monitor, **hdrDisplayMaxLuminance** (clause 6.2.3 in [1]), as specified the next clauses of clause 7.3.

NOTE: The metadata recomputation is not applicable for the table-based mode (**payloadMode 1**).

7.3.2 Scaling factor computation

The scaling factors $scale$, $scaleHor$ and $scaleVer$ shall be computed, as specified in equations (36) up to and including (40):

$$\kappa = v\left(\frac{L_{HDR}}{L_{SDR}}; L_{SDR}\right) \quad (36)$$

$$\lambda = v\left(\frac{L_{HDR}}{L_{pdisp}}; L_{pdisp}\right) \quad (37)$$

$$scale = \frac{(\lambda-1)\times(\kappa+1)}{(\lambda+1)\times(\kappa-1)} \quad (38)$$

$$scaleHor = \frac{1-(1\div\lambda)}{1-(1\div\kappa)} \quad (39)$$

$$scaleVer = Max\left(\frac{1-\lambda}{1-\kappa}; 0\right) \quad (40)$$

where:

- L_{HDR} is the maximum display mastering luminance from the variable **hdrDisplayMaxLuminance** in the structure hdr_characteristics( ) of the reconstruction metadata (clause 6.3.3.4 in [1]);
- L_{SDR} is the maximum SDR luminance (100 cd/m^2);
- L_{pdisp} is the maximum luminance of the presentation display; and

- $v(x;y)$ shall be taken from equations (2) and (3) in clause 7.2.3.1.3.

7.3.3 Recomputation for "Black/white level adaptation" parameters

The parameters to be recomputed for display adaptation for the block "Black/white level adaptation" in Figure 4 and clause 7.2.3.1.4 shall be recomputed as specified by equations (41) and (42):

$$TMWLO_{DA} = TMWLO \times Max(scaleHor;0) \quad (41)$$

where:

- $TMWLO$ is the **tmInputSignalWhiteLevelOffset** from the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1]; and
- $TMWLO_{DA}$ is the recomputed **tmInputSignalWhiteLevelOffset** to be used for display adaptation in the block "Black/white level adaptation" in Figure 4 and clause 7.2.3.1.4.

$$TMBLO_{DA} = TMBLO \times Max(scaleHor;0) \quad (42)$$

where:

- $TMBLO$ is the **tmInputSignalBlackLevelOffset** as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1]; and
- $TMBLO_{DA}$ is the recomputed **tmInputSignalBlackLevelOffset** to be used for display adaptation in the block "Black/white level adaptation" in Figure 4 and clause 7.2.3.1.4.

7.3.4 Recomputation for "Tone mapping curve" parameters

The parameters to be recomputed for display adaptation for the block "Tone mapping curve" in Figure 4 and clause 7.2.3.1.5 shall be recomputed as specified by equations (43) up to and including (51):

$$MIDX = \frac{1-HGC}{SGC-HGC} \quad (43)$$

$$MIDX_{DA} = \frac{MIDX \times (SGC-1)}{2} \times (1-scale) + MIDX \quad (44)$$

$$MIDY_{DA} = -1 \times MIDX_{DA} + MIDX \times (SGC+1) \quad (45)$$

$$SGC_{DA} = \frac{MIDY_{DA}}{MIDX_{DA}} \quad (46)$$

where:

- SGC and HGC shall be computed according to equations (15) and (16) in clause 7.2.3.1.5.

$$para_{DA} = v(Abs(scale);L_{HDR}) \times para \quad (47)$$

where:

- $para$ shall be computed according to equation (17) in clause 7.2.3.1.5;
- and $v(x;y)$ shall be taken from equations (2) and (3) in clause 7.2.3.1.3.

$$HGC_{DA} = \begin{cases} 0, & \text{if } MIDX_{DA} - 1 = 0 \\ Max\left(\frac{MIDY_{DA}-1}{MIDX_{DA}-1};0\right), & otherwise \end{cases} \quad (48)$$

$$\mathbf{shadowGain_{DA}} = \left(\frac{SGC_{DA}}{\lambda} - 0{,}5\right) \times 4 \quad (49)$$

where:

- λ is taken from equation (37), and
- **shadowGain$_{DA}$** is the recomputed **shadowGain** to be used for display adaptation in the block "Tone mapping curve" in Figure 4 and clause 7.2.3.1.5.

$$\mathbf{highlightGain_{DA}} = HGC_{DA} \times 4 \tag{50}$$

where:

- **highlightGain$_{DA}$** is the recomputed **highlightGain** to be used for display adaptation in the block "Tone mapping curve" in Figure 4 and clause 7.2.3.1.5.

$$\mathbf{midToneWidthAdjFactor_{DA}} = para_{DA} \times 2 \tag{51}$$

where:

- **midToneWidthAdjFactor$_{DA}$** is the recomputed **midToneWidthAdjFactor** to be used for display adaptation in the block "Tone mapping curve" in Figure 4 and clause 7.2.3.1.5.

7.3.5 Recomputation for "Adjustment curve" parameters

The parameters to be recomputed for display adaptation for the block "Adjustment curve" in Figure 4 and clause 7.2.3.1.6 shall be recomputed as specified by equations (52) up to and including (55).

First, the points **tmOutputFineTuningX**[i], which are values in the perceptual uniform domain of the SDR image, shall be scaled to the corresponding values for the input HDR image at the mastering display (source picture) by 'going backwards' through the block "Tone mapping curve" and the block "Black/white level adaptation" in the tone mapping process, see Figure 4. Going backwards means that first the inverse tone mapping has to be applied and then the inverse black/white adaptation, see equation (52):

$$x_{i_{HDR}} = BWAD_{inv}\big(TMO_{inv}(x_i)\big) \tag{52}$$

where:

- x_i is the **tmOutputFineTuningX**[i] as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1];
- $x_{i_{HDR}}$ is the scaled **tmOutputFineTuningX**[i] corresponding to the input HDR image at the mastering display (source picture);
- $TMO_{inv}(x)$ is taken from equation (7) in [1], using the values of the variables **shadowGain**, **highlightGain** and **midToneWidthAdjFactor** in the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 in [1]);
- $BWAD_{inv}(Y_{bw}) = Y_{pus}$ as computed by equation (53):

$$Y_{pus} = \left(1 - \frac{255 \times \mathbf{tmInputSignalWhiteLevelOffset}}{510} - \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset}}{2040}\right) \times Y_{bw} + \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset}}{2040} \tag{53}$$

where:

- **tmInputSignalBlackLevelOffset** shall be taken from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 in [1]); and
- **tmInputSignalWhiteLevelOffset** shall be taken from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 in [1]).

Next, the corresponding values for the HDR image at the mastering display, $x_{i_{HDR}}$, are scaled to correspond to the image at the presentation display, using the block "Black/white level adaptation" and the block "Tone mapping curve" in the encoder, see equation (54):

$$x_{i_{DA}} = TMO_{DA}\left(BWAD_{DA}(x_{i_{HDR}})\right) \quad (54)$$

where:

- $x_{i_{DA}}$ is the recomputed **tmOutputFineTuningX**[i] to be used for display adaptation in the block "Adjustment curve" in Figure 4 and clause 7.2.3.1.6;
- $BWAD_{DA}(Y_{pus}) = Y_{bw}$, as computed by equations (5) up to and including (7) in clause 7.2.3.1.4 and using the recomputed **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** from equations (41) to (42) in clause 7.3.3;
- and $TMO_{DA}(X)$ is $TMO(X)$ from equations (8) up to and including (17) in clause 7.2.3.1.5, with the parameters as recomputed according to clause 7.3.4.

Last, the points **tmOutputFineTuningY**[i], are scaled to what they should be for the image at the presentation display with equation (55) using the scaling factor $scaleVer$ derived with equation (40) in clause 7.3.2:

$$y_{i_{DA}} = Min\left((y_i - x_i) \times scaleVer + x_{i_{DA}}\, ;\, 1\right) \quad (55)$$

where:

- y_i is the **tmOutputFineTuningY**[i] as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1]; and
- $y_{i_{DA}}$ is the recomputed **tmOutputFineTuningY**[i] to be used for display adaptation in the block "Adjustment curve" in Figure 4 and clause 7.2.3.1.6.

Annex A (normative): SL-HDR reconstruction metadata using HEVC

Annex A of ETSI TS 103 433-1 [1] specifies the format of the SEI message that carries the SL-HDR reconstruction metadata for HEVC specification [5] as well as the mapping between the syntax elements of this SEI message and the dynamic metadata variables provided in clause 6 of [1].

Annex A of [1] shall apply to the present document, except for the following.

Clause A.2.2.4 of [1] "SL-HDR SEI message semantics":

- In bitstreams conforming to the present document, the value of sl_hdr_mode_value_minus1 shall be equal to 1.
- In bitstreams conforming to the present document, the value of sl_hdr_spec_major_version_idc shall be equal to 1.
- In bitstreams conforming to the present document, the value of sl_hdr_spec_minor_version_idc shall be equal to 0.
- In bitstreams conforming to the present document, the value of coded_picture_info_present_flag shall be equal to 0.
- In bitstreams conforming to the present document, the value of sl_hdr_extension_present_flag shall be equal to 0.
- Decoders that comply with the present document shall ignore the values of coded_picture_primaries, coded_picture_max_luminance and coded_picture_min_luminance, if they are present in a bitstream.
- In bitstreams conforming to the present document, the value of target_picture_max_luminance, if present, shall be equal to 100.
- In bitstreams conforming to the present document, the value of target_picture_min_luminance, if present, shall be equal to 0.
- In bitstreams conforming to the present document, the values of matrix_coefficient_value[i] shall be set as specified in Table F.1 for all values of i.
- In bitstreams conforming to the present document, the values of chroma_to_luma_injection[i] shall be equal to 0 for all values of i.
- In bitstreams conforming to the present document, the values of k_coefficient_value[i] shall be equal to 0 for all values of i.
- Decoders that comply with the present document shall ignore the values of sl_hdr_extension_6bits and sl_hdr_extension_data_byte[i] for all values of i, if they are present in a bitstream.
- In bitstreams conforming to the present document, gamut_mapping_mode equal to 4 and 5 specifies predetermined values used by the gamut mapping process (documented in Annex D) to respectively map the P3D65 (preset #3) or the BT.2020 (preset #4) gamut of the reconstructed picture to BT.709 gamut. In bitstreams conforming to the present document, the value of gamut_mapping_mode shall be in the range of 0 to 1, inclusive, in the range of 4 to 5, inclusive, or in the range of 64 to 127, inclusive. See also Table 2, Table 3 and Table 4 in clause 6.

Annex B (normative):
SL-HDR reconstruction metadata using AVC

Annex B of [1] specifies the format of the SEI message that carries the SL-HDR reconstruction metadata for AVC specification [4] as well as the mapping between the syntax elements of this SEI message and the dynamic metadata variables provided in clause 6 of [1].

AVC is not supported by the present document.

Annex C (informative): HDR-to-SDR decomposition principles and considerations

The HDR-to-SDR decomposition process aims at converting the input linear-light 4:4:4 HDR, to an SDR compatible version (also in 4:4:4 format). The process also uses side information such as the mastering display peak luminance, colour primaries, and the colour space in which the HDR and SDR pictures are represented. In the present document, the HDR-to-SDR conversion operates without changes of the colour gamut or space. The HDR and SDR pictures are defined in the same colour gamut or space. However, the pre-processor may include optional gamut mapping parameters in the dynamic metadata that the IRD can use to perform gamut mapping after reconstruction of the HDR/SDR signal to a different colour gamut or space than the one of the input HDR picture (source picture).When this is not true, a preliminary gamut mapping or colour conversion process may be applied to convert the HDR picture from its native colour gamut or space to the target SDR colour gamut or space.

The HDR-to-SDR decomposition process generates an SDR backward compatible version from the input HDR signal, using an invertible process that guarantees a high quality reconstructed HDR/SDR signal.

The process is summarized in Figure C.1.

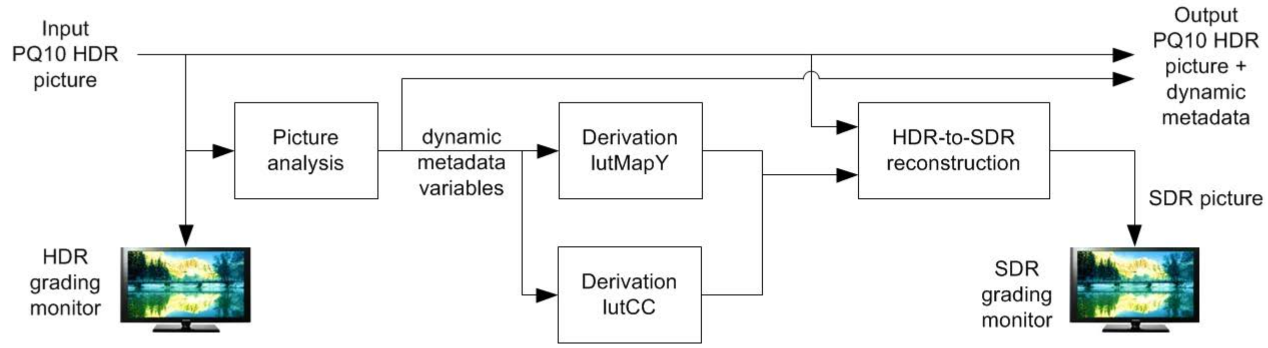

Figure C.1: synopsis of the HDR-to-SDR decomposition process

The input PQ HDR picture is assumed to be graded on an HDR monitor. Only the HDR monitor is shown in Figure C.1 without the rest of the HDR grading process. However, the characteristics of the HDR grading monitor are used in the picture analysis block and are part of the generated metadata.

First, from the input HDR picture (source picture) and its characteristics, the dynamic metadata variables are derived in the block "Picture analysis". This may be an automatic process, e.g. a process as described in clause C.3 of [1], in which case the blocks "Derivation lutMapY", "Derivation lutCC" and "HDR-to-SDR reconstruction" as well as the SDR grading monitor are not required, or a process where a human grader observes the SDR grading monitor while adjusting the metadata parameters for an optimally graded SDR picture.

In case the SDR grading monitor is used, the look-up tables $lutMapY$ and $lutCC$ are computed as specified in clauses 7.2.3.1 and 7.2.3.2, from the dynamic metadata variables. These look-up tables are used in the "HDR-to-SDR reconstruction" block as specified in clause 7.2.4 to generate the SDR output for the SDR grading monitor.

The output to the video encoder for e.g. video distribution is the output PQ HDR picture, together with the dynamic metadata variables. The dynamic metadata variables are stored in the SEI messages as specified by Annex A of [1] as adapted by Annex A of the present document for HEVC.

Annex D (informative): Gamut mapping

This Annex provides the description of a (forward) gamut mapping (i.e. gamut compression) process that could apply in a display adaptation scenario typically when the output HDR picture of the HDR-to-HDR/SDR reconstruction process is provided in a wide colour gamut (e.g. Recommendation ITU-R BT 2020 as specified by the variable **hdrPicColourSpace**), and is different from the colour gamut supported by the target presentation display (typically Recommendation ITU-R BT 709 as specified by the variable **sdrPicColourSpace**).

Figure D.1 illustrates a typical scenario where (forward) gamut mapping is required. In this example, the HDR content is graded on a P3D65 HDR monitor (signalled by **hdrDisplayColourSpace**) and represented in a BT.2020 colour space (signalled by **hdrPicColourSpace**). However, the target HDR or SDR presentation display supports only BT.709 colour space (signalled by **sdrPicColourSpace**). Therefore, a (forward) gamut mapping from Recommendation ITU- R BT.2020-2 [3] to BT.709 [2] is required in addition to the dynamic range mapping from HDR to HDR/SDR.

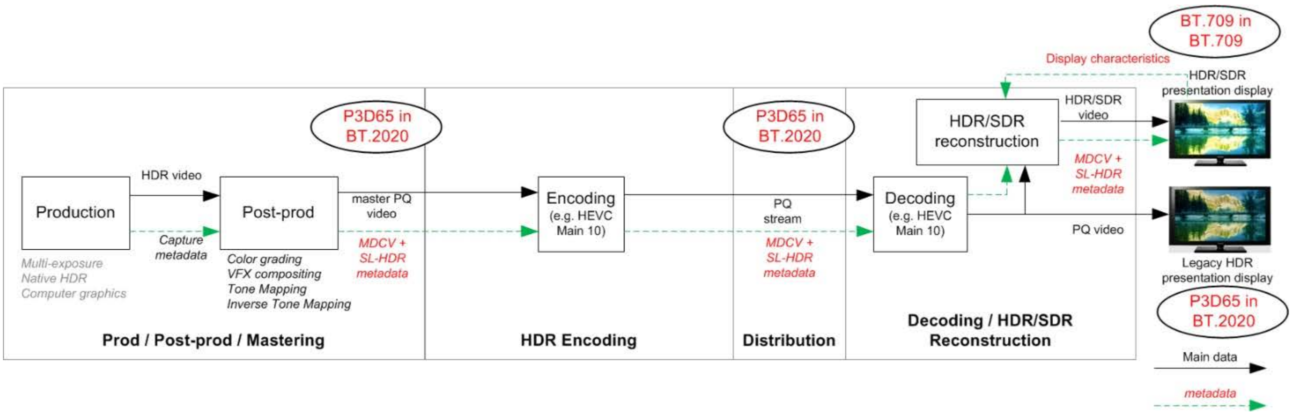

Figure D.1: Example of use case requiring a gamut mapping

Unlike ETSI TS 103 433-1 [1] that applies a gamut mapping process during the (post-)production stage, the optional gamut mapping process documented in the present document may be applied in the IRD during the post-processing stage.

Notations and definitions of clause D.2 of [1] should apply to this Annex. The gamut mapping process used in the present document should be the forward gamut mapping process documented in clause D.3 of [1].

The interface of SL-HDR2 reconstruction with the gamut mapping process is as documented in clause D.4.2 of [1].

Annex E (informative): Embedded data on CE digital video interfaces

E.1 Introduction

Annex E defines the methods to transmit two kinds of data over CE digital video interfaces (e.g. HDMI, DisplayPort):

1) 1SL-HDR metadata in the form of the SL-HDR Information SEI message, sl_hdr_info(), see clause A.2.2 of [1];

2) Graphics Indicator bit.

The SL-HDR metadata can consist of Mastering Display Colour Volume (MDCV) SEI messages and SL-HDR Information SEI messages. Alternatively, the SL-HDR Information SEI message can contain MDCV metadata, see the description of the **src_mdcv_info_present_flag** field in clause A.2.2.4 of [1]. When transmitting SL-HDR metadata using the interface specified in this Annex, and the **src_mdcv_info_present_flag** in a received SL-HDR Information SEI message equals zero, the contents of the received MDCV SEI message is copied to the structure sl_hdr_info() and the **src_mdcv_info_present_flag** field is set to one before transmitting the SL-HDR Information SEI message over the CE digital video interface.

The method to transmit SL-HDR metadata as specified in this Annex, is only suitable for applications that use the parameter-based mode of SL-HDR (payloadMode 0).

Transmission of the Graphics Indicator bit can also be combined with the method to transmit SL-HDR metadata as specified in this Annex.

E.2 Supported video formats

Data embedding is supported for video formats with the following characteristics:

- RGB 4:4:4, YCbCr 4:4:4, YCbCr 4:2:2 and YCbCr 4:2:0;
- at least 10 bits per component (12 or more recommended) for transmission of SL-HDR Information SEI messages;
- at least 12 bits per component for Graphics Indicator bit;
- at least 1 280 pixels on a line (1 920 or more recommended) for RGB 4:4:4, YCbCr 4:4:4 and YCbCr 4:2:2;
- at least 2 560 pixels on a line (3 840 or more recommended) for YCbCr 4:2:0.

E.3 Metadata packets

E.3.1 Introduction

A metadata packet containing an SL-HDR Information SEI message is embedded in the first line of video frames. Clause E.3.2 defines the syntax of the metadata packets, clause E.3.3 defines the semantics of the metadata packet and clause E.3.4 defines the embedding mechanism.

E.3.2 Metadata packet syntax

An SL-HDR Information SEI message is contained in the payload of a variable length metadata packet. The syntax of the metadata packets is defined in Table E.1. The semantics of the packets are defined in clause E.3.3.

Table E.1: Metadata packet syntax

Syntax	Descriptor
metadata_packet( ) {	
content_id	u(8)
length	u(8)
sl_hdr_info() (see note)	
while (!byte_aligned( ))	
packet_bit_equal_to_zero /* equal to 0 */	f(1)
for (i=0; i < num_reserved_bytes: i++) {	
reserved	u(8)
}	
packet_edc	u(32)
}	
NOTE: See clause A.2.2 of [1].	

E.3.3 Metadata packet semantics

A metadata packet consists of a 2-byte header, a variable length payload and a 4-byte error detection code (EDC). The payload is an integer number of bytes containing the SL-HDR Information SEI message for a single video frame, starting from the first byte after the length field. Optionally reserved bytes may be added to the metadata_packet().

content_id identifies the type of content contained in the packet according to the description in Table E.2.

Table E.2: content_id description

content_id	Description
0x38	The packet contains an SL-HDR Information SEI message that may be different from the SL-HDR Information SEI message contained in the previous video frame
0x39	The packet contains an SL-HDR Information SEI message that is a repetition of the SL-HDR Information SEI message contained in the previous video frame
other	Reserved

length is an unsigned integer indicating the number of SL-HDR Information SEI message bytes and reserved bytes contained in the packet.

byte_aligned( ) is specified in clause 7.2 of the HEVC specification [5].

packet_bit_equal_to_zero is one bit equal to 0.

reserved is an unsigned integer. Additional bytes may be added in a future version of the present document. For the current version num_reserved_bytes is typically 0, but implementations should be able to deal with reserved bytes in the packet.

packet_edc is a 4-byte field containing an error detection code computed over all bytes of the packet preceding packet_edc. This EDC uses a CRC-32 polynomial with the following characteristics (refer to [i.4]):

Width: 32

Poly: 0x04C11DB7

Init: 0x00000000

RefIn: False

RefOut: False

XorOut: 0x00000000

Check: 0x89A1897F

E.3.4 Metadata packet embedding

Metadata packets containing the SL-HDR Information SEI message are embedded in the first video line of each frame. The data applies to the frame following the one in which it is embedded.

One bit per pixel is available for including the data. It depends on the video format which bits are used for embedding the data, as follows.

For RGB 4:4:4 bit 0 (LSB) of all B samples are used.

For YCbCr 4:4:4 bit 0 (LSB) of all Cb samples are used.

For YCbCr 4:2:2 bit 0 (LSB) of all Cb and Cr samples are used.

For YCbCr 4:2:0 bit 0 (LSB) of all Cb samples are used.

NOTE: The bit allocation as described above is independent of the number of bits (10, 12 or 16) per sample. For example, if 10 bit video data from the decoder is output as 12 bit YCbCr 4:2:2, bit 0 is used for the metadata packet embedding on the video interface.

Bits available for embedding the metadata packets are numbered from 0 to N-1 in the order of the transmission of the samples on the interface, where N is the number of pixels on a video line.

A stream of bytes, numbered from 0 to (N/8 - 1), is mapped onto this stream of bits as depicted in Figure E.1.

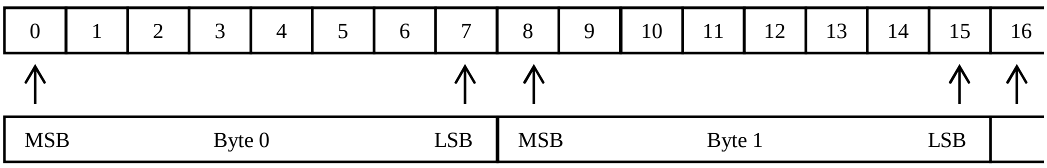

Figure E.1: Mapping metadata on video

The stream of bytes contains at least one instance of the metadata packet. Two instances with the same content are included if sufficient bytes are available.

The first instance is included sequentially from the first byte of the stream. The second instance is included sequentially from exactly halfway the stream of bytes. Bytes of the stream that do not contain metadata packet data are set to 0.

EXAMPLE: A 1 920 pixel line allows for a stream of 240 bytes, mapped onto 1 920 bits. If the SL-HDR Information SEI message has a length of 68 bytes, the metadata packet length will be 74 bytes. The first instance will be contained by bytes 0 to 73, the second instance will be contained by bytes 120 to 193 of the stream of bytes. All other bytes are 0.

E.4 Graphics Indicator bit

Source devices that send SL-HDR Information SEI messages over the CE digital video interface are recommended to also support the generation and transmission of a Graphics Indicator bit for each output pixel. The Graphics Indicator bit flags for the pixel that it should be treated by the Sink device as a graphics overlay pixel.

This bit is included as the least significant bit (LSB) of the Y-component (in YCbCr mode) or the G-component (in RGB mode) on a 12-bit or 16-bit video output.

Source devices that do not support the generation of the Graphics Indicator bit set the LSB of the Y-component (in YCbCr mode) or the G-component (in RGB mode) on 12-bit and 16-bit video outputs to 0.

E.5 Signalling SL-HDR Dynamic Metadata

E.5.1 Introduction

SL-HDR compliant display devices that have the ability to receive SL-HDR metadata transmitted according to the method described in this Annex and/or have the ability to read Graphics Indicator bits indicate SL-HDR support to source devices by means of a Vendor-Specific Video Data Block (VSVDB) in their EDID. See clause E.5.2 for details.

Source devices signal the presence of SL-HDR metadata and/or Graphics Indicator bits in the video stream according to the method specified in this Annex by means of the SL-HDR Dynamic Metadata InfoFrames. See clause E.5.3 for details.

E.5.2 VSVDB to signal SL-HDR support

The format of the VSVDB to signal SL-HDR support is shown in Table E.3.

Table E.3: VSVDB for SL-HDR

Byte #	7	6	5	4	3	2	1	0
1	Tag Code = 0x07 (Use extended)				Length = 5			
2	Extended tag Code = 0x01 (Vendor-specific Video Data Block)							
3	IEEE CID third two hex digits = 0xB1							
4	IEEE CID second two hex digits = 0x9F							
5	IEEE CID first two hex digits = 0xEA							
7	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	Supports_ SL-HDR_ Graphics_ Indicator	Supports_ SL-HDR_ Dynamic_ Metadata

Supports_SL-HDR_Graphics_Indicator set to 1 indicates that the Sink device has the ability to read the Graphics Indicator bits. If this bit is zero, Graphics Indicator bits (if present) will be ignored.

Supports_SL-HDR_Dynamic_Metadata set to 1 indicates that the Sink device has the ability to receive dynamic metadata transmitted according to the method described in this Annex for all video formats with characteristics defined in clause F.2 and supported by the Sink device. If this bit is zero, the Sink device does not support receiving dynamic metadata according to the method described in this Annex.

E.5.3 SL-HDR Dynamic Metadata InfoFrame

The format of the Packet Header and the Packet Payload of the SL-HDR Dynamic Metadata InfoFrame is shown in Table E.4. It includes an SL-HDR InfoFrame Type Data parameter, defined in Table E.5.

The SL-HDR Dynamic Metadata InfoFrame is sent at least once per two video frames.

Table E.4: SL-HDR Dynamic Metadata InfoFrame

Packet Header

Byte \ Bit#	7	6	5	4	3	2	1	0
HB0	InfoFrame Type Code = 0x01 (Vendor-Specific)							
HB1	Version = 0x01							
HB2	0	0	0	Length = 4				
Packet Payload								
Packet Byte #	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
PB0	Checksum							
PB1	IEEE CID third two hex digits = 0xB1							
PB2	IEEE CID second two hex digits = 0x9F							
PB3	IEEE CID first two hex digits = 0xEA							
PB4	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	Rsvd(0)	SL-HDR_InfoFrame_ Type_Data	
PB5 - PB27	Reserved (0)							

Table E.5: SL-HDR InfoFrame Type Data definition

Value	SL-HDR_InfoFrame_Type_Data
0	No Dynamic Metadata present
1	SL-HDR_Dynamic_Metadata_present (only)
2	SL-HDR Graphics Indicator Bits present (only)
3	Both SL-HDR_Dynamic_Metadata and SL-HDR_Graphics_Indicator_Bits present

Annex F (informative):
Error-concealment: recovery in post-processor from metadata loss or corruption

F.1 Introduction

SL-HDR2 streams are designed to be supported by video distribution workflows. In the present document, SL-HDR2 parameters are conveyed in SEI messages that are seamlessly embedded in the HDR10 coded video bitstream. In the unlikely event that a portion or all the SEI messages related to SL-HDR2 are pruned by a distribution equipment (e.g. when an SL-HDR2 stream is decoded, mixed, re-encoded, redistributed, etc. by certain affiliate networks), this Annex provides means to recover parameters default values for use in the SL-HDR2 post-processor. The methods proposed in this Annex are also applicable in case that a corruption of metadata is detected.

It is expected that a distribution network leveraging an SL-HDR2 stream indicates an SL-HDR-enabled service at the system layer level. Thus, a loss of metadata related to the SL-HDR2 stream could be detected.

Recovery values helpful for reconstructing the SDR picture and HDR picture with peak luminance adapted to target display using display adaptation are provided in clause F.2.

The methods to obtain default parameters may also be applied in case it is desirable to replace the original metadata by a fixed tone mapping function, e.g. when graphics overlays are inserted on the decoded video by a mid-device (e.g. STB) which transmits SL-HDR reconstruction metadata as well as the mixed video to an SL-HDR capable TV.

Anyway, it is recommended to reconstruct the HDR video before image manipulations such as graphics overlays for use in professional environments.

It is expected that the static metadata carried in a Mastering Display Colour Volume SEI message (or equivalent message carrying ST 2086 information), helpful during the HDR-to-HDR/SDR reconstruction process, are prone to resist to all sorts of distribution workflows as these static metadata are specified both by SMPTE (production side for contribution networks) and MPEG/ITU-T (distribution side for distribution networks using AVC or HEVC). Besides, static metadata are generally defined and fixed for an entire stream or content. Eventually, MDCV SEI message/SMPTE ST 2086 metadata are being documented in all major applicative standards (ATSC, DVB, CTA...) and it is likely that interfaces to provide this information may be supported by most of the industry stakeholders. Thus, a recovery strategy may consist of recovering adjusted (but suboptimal) SL-HDR2 parameter values thanks to information carried in MDCV SEI/ST 2086 messages. A recovery procedure for the variable **shadow_gain_control** based on this assumption is provided in clause F.3.

In case all SEI messages related to SL-HDR2 are lost, a recovery procedure for the variable **shadow_gain_control** is documented in clause F.4.

F.2 Metadata values for recovery mode

The metadata used for obtaining the HDR/SDR reconstructed picture may have their values recovered in case of loss or corruption. Table F.1 proposes recovery values for the syntax elements of the SL-HDR Information SEI message that are involved in the HDR-to-HDR/SDR reconstruction process.

Typically, the values of **matrix_coefficient_value[i]** provided in Table F.1 are computed as follows:

$$\mathbf{matrix\_coefficient\_value}[\,\mathbf{i}\,] = Floor(\, c(i) \times 256 + 512 + 0{,}5) \quad \text{(F.1)}$$

with $c(i) = \{1{,}4746;\ -0{,}1646;\ -0{,}5714; 1{,}8814\}$, if BT.2020 primaries (coefficients computed from [3])

or $c(i) = \{1{,}5748;\ -0{,}1874;\ -0{,}4681; 1{,}8556\}$, if BT.709 primaries (coefficients computed from [2]).

It is noted that **matrix_coefficient_value**[i] default values correspond to the canonical coefficients of the Y'CbCr-to-R'G'B' conversion matrix for either BT.2020 or BT.709 colour space. By default, the BT.2020 matrix coefficients may be selected for the recovery procedure.

Table F.1: Default metadata values for recovery mode

Syntax element	Recovery value
sl_hdr_payload_mode	0
matrix_coefficient_value[i]	{889; 470; 366; 994}, if BT.2020 {915; 464; 392; 987}, if BT.709
chroma_to_luma_injection[i]	{0;0}
k_coefficient_value[i]	{0; 0; 0}
tone_mapping_input_signal_black_level_offset	0
tone_mapping_input_signal_white_level_offset	0
shadow_gain_control	if MDCV SEI message is present, see clause F.3 otherwise, see clause F.4
highlight_gain_control	255
mid_tone_width_adjustment_factor	64
tone_mapping_output_fine_tuning_num_val	0
saturation_gain_num_val	0

F.3 Recovery of shadow_gain_control with MDCV SEI message

This clause proposes a recovery procedure, for the value of the parameter **shadow_gain_control**, which is applicable when MDCV SEI/ST 2086 messages are available.

Indeed, the Mastering Display Colour Volume SEI message contains information on the source picture mastering display nominal maximum luminance (**max_display_mastering_luminance** that is mapped to **hdrDisplayMaxLuminance** as specified by clause A.3.2 of [1]) that may be used to adjust the value of **shadow_gain_control** as follows:

$$\mathbf{shadow\_gain\_control} = Clip3(0\,;255\,;\,Floor(r_s(\mathbf{hdrDisplayMaxLuminance}) \times 127{,}5 + 0{,}5)) \quad \text{(F.2)}$$

with $r_s(x) = \frac{7{,}5}{\ln\left(1+4{,}7\times\left(\frac{x}{100}\right)^{\frac{1}{2{,}4}}\right)} - 2$

F.4 Recovery of shadow_gain_control without MDCV SEI message

It is likely that at the service level information or for a specific workflow the value of **hdrDisplayMaxLuminance** is known. This value can be input in the recovery procedure described in clause F.3. **hdrDisplayMaxLuminance** is set to the maximum luminance of the presentation display when available, otherwise it is arbitrarily set to a value of 1 000 cd/m². This value corresponds to the currently observed reference maximum display mastering luminance in most of the HDR markets.

Annex G (informative): ETSI TS 103 433 signalling in CTA-861-G

Information on how ETSI TS 103 433 multi-part deliverable [i.8] metadata can be carried on CE digital interfaces (e.g. HDMI) with dynamic metadata support can be found in Annex G of [1].

For CE digital interfaces without dynamic metadata support, an alternative method is described in Annex F.

Annex H (informative): Minimum and maximum value of L_{pdisp} for display adaptation

In case L_{pdisp} is anywhere in between 100 cd/m² and the maximum luminance of the HDR grading monitor, **hdrDisplayMaxLuminance** (clause 6.2.3 in [1]), the metadata recomputation for display adaptation of clause 7.3 is in effect an interpolation.

It is possible to recompute the metadata using the same procedure of clause 7.3 to perform display adaptation for a presentation display with a value of L_{pdisp} that is higher than the maximum luminance of the HDR grading monitor. Because this is now an extrapolation, care should be taken not to use values for L_{pdisp} that are too high.

This clause offers a recommendation for the lower and upper boundary of L_{pdisp} for applying the procedure of clause 7.3 for display adaptation.

Display adaptation should not be used for a value of L_{pdisp} lower than L_{pdisp_min}, or higher than L_{pdisp_max}, see equations (H.1) and (H.2).

$$L_{pdisp\_min} = 100 \text{ cd/m}^2 \quad \text{(H.1)}$$

$$L_{pdisp\_max} = \begin{cases} L_{HDR} \times 2, & \text{if } L_{HDR} \leq 1\,000\ cd/m^2 \\ Min(Max(L_{HDR} \times 1{,}25;\, 2\,000);\ 10\,000), & \text{otherwise} \end{cases} \quad \text{(H.2)}$$

where:

- L_{HDR} is the HDR mastering display maximum luminance **hdrDisplayMaxLuminance.**

Annex I (informative): Change History

Date	Version	Information about changes
V0.0.1	March 2017	Early Draft
V0.0.2	July 2017	Stable Draft
V0.0.3	September 2017	Second Stable Draft
V0.0.4	November 2017	Draft for Approval

History

Document history		
V1.1.1	January 2018	Publication