# ETSI TS 103 433-2 V1.2.1 (2020-03)

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)**

Reference

RTS/JTC-051-2

Keywords

broadcasting, content, digital, distribution, HDR, HDTV, UHDTV, video

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

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# Introduction

### Motivation

Today Ultra HD services have been launched or are being launched by broadcasters and network operators in many regions of the world. Besides higher resolution, wider colour gamut and higher frame rate, High Dynamic Range is a highly demanded feature.

The goal of ETSI TS 103 433-1 [1], SL-HDR1, is to standardize a single layer HDR system addressing direct SDR 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 present document. Clause 2 provides references used in the present document. Clause 3 gives essential definition of terms, 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. Annex I describes a variation (called SL-HDR2+), where the distributed signal has a maximum luminance in between the maximum luminance of SDR and that of the original HDR signal. Decoders according to Annex I can reconstruct the original HDR signal, the SDR signal and an output signal with any maximum luminance in between that of SDR and the original HDR signal, where decoders according to clause 7 can reconstruct an output signal with any maximum luminance in between that of SDR and the distributed HDR signal. Finally, Annex J provides information on SL-HDR metadata indication for CMAF based applications, and informative Annex K provides information on the use of SL-HDR in DVB Services.

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

**Table 1: Structure of the present document**

| Clause/Annex # | Description | 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 of terms, symbols and 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 | Informative |
| 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 |
| Annex I | SL-HDR2+ and adaptive presentation display adaptation | Informative |
| Annex J | SL-HDR metadata indication for CMAF based applications | Informative |
| Annex K | Use of SL-HDR in DVB Services | Informative |
| Annex L | Change History | 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: "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 (06-2019): "Advanced video coding for generic audiovisual services".

[5] Recommendation ITU-T H.265 (11-2019): "High efficiency video coding".

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

[7] SMPTE ST 2086:2018: "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-G, November 2016: "A DTV Profile for Uncompressed High Speed Digital Interfaces".

[i.2] Recommendation ITU-R BT.2035: "A reference environment for evaluation of HDTV program material or completed programmes".

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

NOTE: Available at https://www.zlib.net/crc_v3.txt.

[i.4] SMPTE Engineering Guideline EG 28-1993: "Annotated Glossary of Essential Terms for Electronic Production".

[i.5] SMPTE ST 2094-20:2016: "Dynamic Metadata for Color Volume Transform - Application #2".

[i.6] SMPTE ST 2094-30:2016: "Dynamic Metadata for Color Volume Transform - Application #3".

[i.7] ETSI TS 103 433 (all parts): "High-Performance Single Layer Directly Standard Dynamic Range (SDR) Compatible High Dynamic Range (HDR) System for use in Consumer Electronics devices".

# 3 Definition of terms, symbols, abbreviations and conventions

## 3.1 Terms

For the purposes of the present document, the following terms 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.4]

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

**original picture:** output HDR picture of post-production, HDR picture input to the encoder

NOTE: The source picture is an original picture which characteristics may have been adjusted for distribution.

**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.7]

**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.2], 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

NOTE: 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

NOTE: 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:

ATSC Advanced Television Systems Committee
AVC Advanced Video Coding
BT Broadcasting service (television)
CE Consumer Electronics
CID Company ID
CIE Commission Internationale de l'Eclairage
CLVS coded layer-wise video sequence
CMAF Common Media Application Format
CRC Cyclic Redundancy Check
EDC Error Detection Code
EDID Extended Display Identification Data
EOTF Electro-Optical Transfer Function
HDMI High-Definition Multimedia Interface
HDR High Dynamic Range
HDRB HDR Blue component
HDRG HDR Green component
HDRR HDR Red component
HDRY HDR Y component
HEVC High Efficiency Video Coding
HGC Highlight Gain Control
IRD Integrated Receiver Decoder
LHDR maximum luminance of the HDR mastering display
LSB Least Significant Bit
LSDR maximum luminance of the SDR mastering display
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

| | |
|---|---|
| SDR | Standard Dynamic Range |
| SDRLUT | Standard Dynamic Range Look-Up Table |
| SEI | Supplemental Enhancement Information |

NOTE: As in AVC and HEVC.

| | |
|---|---|
| SGC | Saturation Gain Control |
| SL-HDR | Single Layer High Dynamic Range |
| SL-HDRI | Single Layer High Dynamic Range Information |
| SMPTE | Society of Motion Picture and Television Engineers |
| ST | Standard |
| STB | Set Top Box |
| TMBLO | Tone Mapping Input Signal Black Level Offset |
| TMO | Tone Mapping Operator |
| TMWLO | Tone Mapping Input Signal White Level Offset |
| VSVDB | Vendor-Specific Video Data Block |
| WCG | Wide Colour Gamut |

## 3.4 Conventions

Unless otherwise stated, the following conventions 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 ETSI TS 103 433-1 [1], Annex A of ETSI TS 103 433-1 [1], and Annex B of ETSI TS  03 433-1 [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 ETSI TS 103 433-1 [1] and in Annex B of ETSI TS 103 433-1 [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 backwards 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.5] and SMPTE ST 2094-30 [i.6] 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.

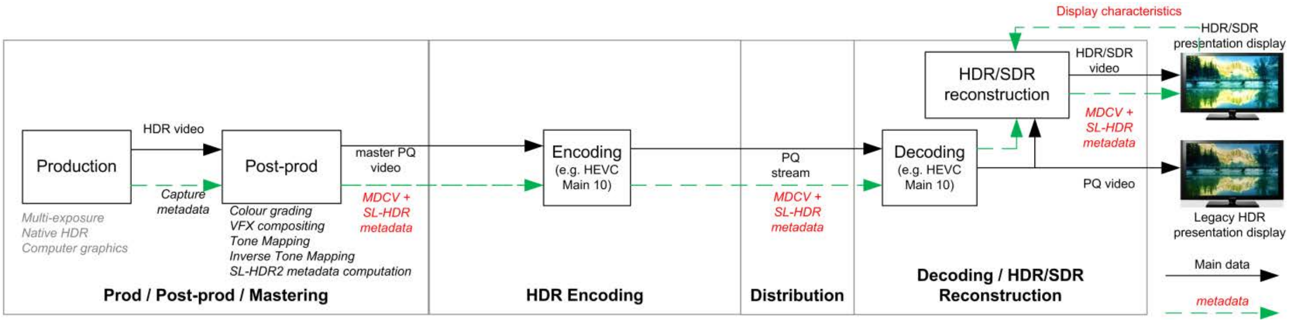



**Figure 1: Example of an HDR end-to-end system**

# 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.

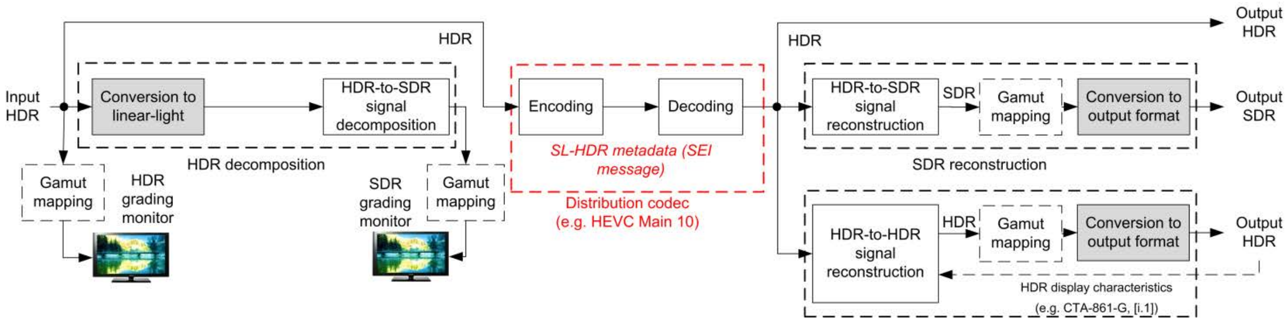



**Figure 2: HDR system architecture overview**

An alternative system architecture where the maximum luminance of the distributed signal is in between that of the SDR signal and that of the original picture is specified in Annex I.

# 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 of the original picture to any maximum luminance between SDR (100 cd/m²) and a value higher than the original picture 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 and mapping as specified in Annex A of the present document, and taking the following exceptions into account.

**SL-HDR1 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 either 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 decoded HDR picture, enables reconstruction of either 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 source picture (HDR) and not the target picture (SDR) is intended to be encoded and transmitted on distribution networks.

- Clauses 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 | 1 |
| satGlobal1SegRatio | $\frac{7}{8}$ |
| satGlobal2SegRatioWCG | $\frac{29}{64}$ |
| satGlobal2SegRatioSCG | $\frac{29}{64}$ |
| lightnessMappingMode | 2 |
| croppingModeSCG | 0 |
| hueAdjMode | 3 |
| huePreservationRatio[ c ] | $\left\{\frac{7}{8}; \frac{7}{8}; \frac{7}{8}; \frac{7}{8}; \frac{6}{8}; \frac{7}{8}\right\}$ |
| hueAlignCorrectionPresentFlag | 1 |
| hueAlignCorrection[ c ] | {4; 1; 2; 4; 5; 1} |
| chromAdjPresentFlag | 0 |

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

| Gamut mapping variable | Variable value |
|---|---|
| satMappingMode | 1 |
| satGlobal1SegRatio | $\frac{7}{8}$ |
| satGlobal2SegRatioWCG | $\frac{29}{64}$ |
| satGlobal2SegRatioSCG | $\frac{29}{64}$ |
| lightnessMappingMode | 2 |
| croppingModeSCG | 0 |
| hueAdjMode | 2 |
| hueGlobalPreservationRatio | $\frac{7}{8}$ |
| hueAlignCorrectionPresentFlag | 1 |
| hueAlignCorrection[ c ] | {4; 1; 2; 4; 5; 1} |
| 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 variables specified in clause 6.2 of [1] and retrieved from parsed and mapped (see clause A.2.3 of [1]) syntax elements of SL-HDR2 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/$m^2$.

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 and clause 7.2.3.3).
- 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 and clause 7.2.3.4).
- 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].

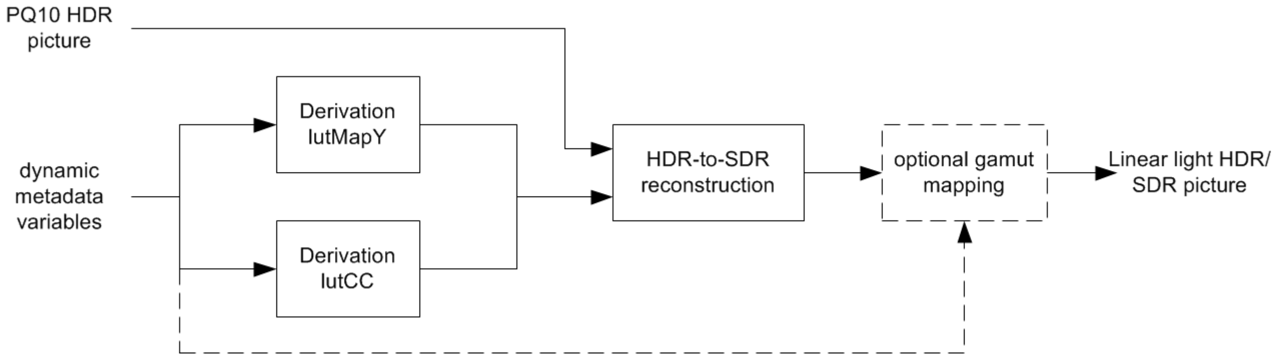



**Figure 3: Overview of the SDR reconstruction process**

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 a value higher than 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). See Annex H for the recommended range of values of $L_{pdisp}$ to perform display adaptation with.

## 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.

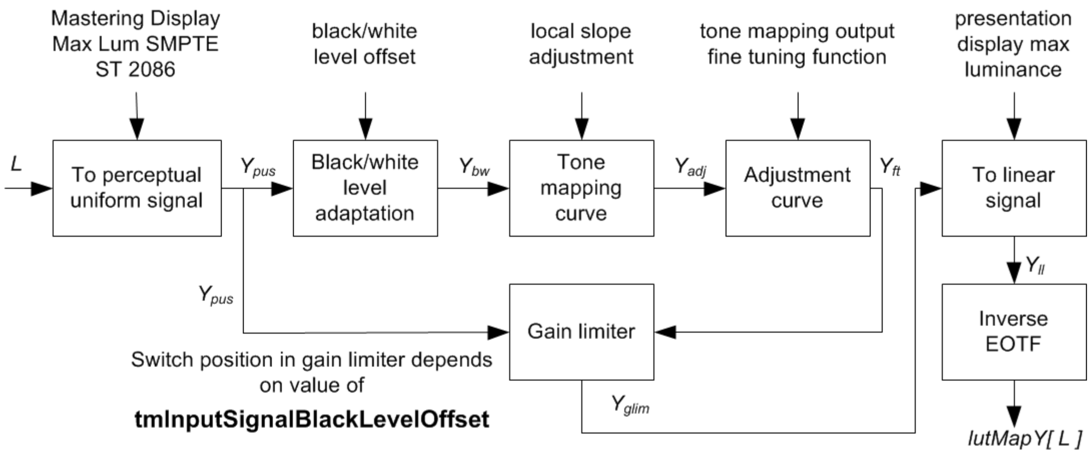



**Figure 4: Tone mapping process**

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 $\gamma = 2{,}4$, 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 $Y_{pus}$ 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.

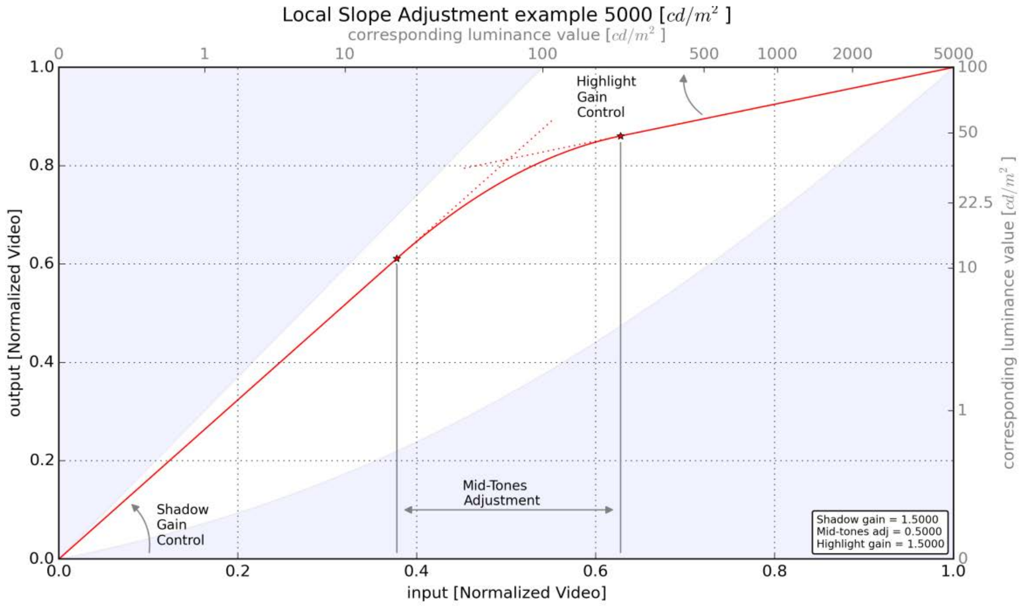



**Figure 5: Tone mapping curve shape example**

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.

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

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

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

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

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

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

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

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

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

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 a 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 an inferred 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 7.3.5 in case $L_{pdisp}$ is greater than 100 cd/m².

NOTE: The recomputation procedure in clause 7.3.5 may extend the list of point pairs with additional inferred points.

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

An example fine tuning curve is shown in Figure 6.

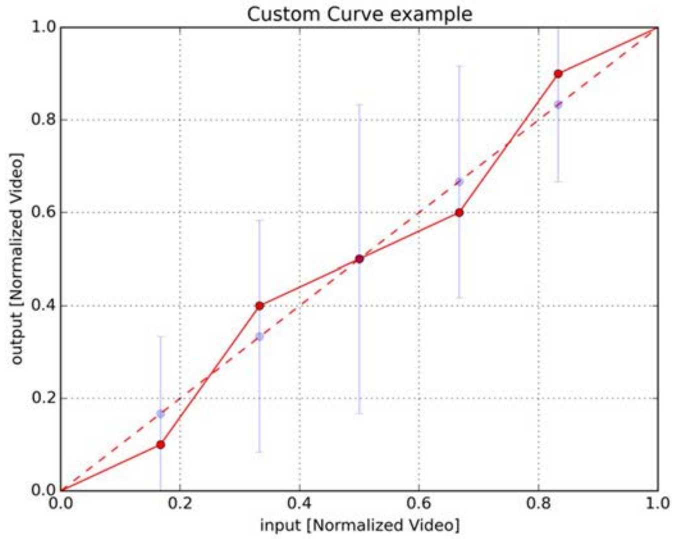



**Figure 6: Example fine-tuning curve**

#### 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),

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

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

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), (22) and (23) and shall be based on the maximum luminance $L_{pdisp}$ of the presentation display, see clause 7.2.1.

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

$$\rho(y) = 1 + (33-1) \times \left(\frac{y}{10000}\right)^{\frac{1}{2,4}} \quad (22)$$

$$Y_{ll} = v_{inv}(Y_{glim}; L_{pdisp}) \quad (23)$$

#### 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 (24):

$$lutMapY[\,L\,] = invPQ(Y_{ll} \times L_{pdisp}) \quad (24)$$

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 (25):

$$lutCC[0] = 0{,}125 \quad (25)$$

For each luma value $Y$ in 1..( $maxSampleVal$ - 1 ), $lutCC$[ $Y$ ] shall be derived as specified in equation (26):

$$lutCC[Y] = Min\left(lutCC[0]\ ;\ \frac{1 + c(L_{HDR}; L_{SDR}; L_{pdisp}) \times {Y_n}^{2,4}}{Y_n \times Max\left(R_{sgf} \div 255\ ;\ R_{sgf} \times g(Y_n)\right)} \times \frac{1}{maxSampleVal - 1}\right) \quad (26)$$

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 (27):

$$c(L_{HDR}; L_{SDR}; L_{pdisp}) = 1 - \frac{invPQ(L_{pdisp}) - invPQ(L_{SDR})}{invPQ(L_{HDR}) - invPQ(L_{SDR})} \quad (27)$$

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 (28):

$$lutMapY[\ Y\ ] = f_{luma}\left(\frac{Y}{maxSampleVal-1}\right) \quad (28)$$

### 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 (29):

$$lutCC[\ Y\ ] = f_{chroma}\left(\frac{Y}{maxSampleVal-1}\right) \quad (29)$$

## 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 HDR picture colour space **hdrPicColourSpace** (clause 6.3.3.2 of [1]);
- 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 (30):

$$\begin{cases} U_{post1} = HDR_{cb}[x][y] - midSampleVal \\ V_{post1} = HDR_{cr}[x][y] - midSampleVal \end{cases} \quad (30)$$

where:

- *midSampleVal* is equal to *maxSampleVal* / 2 = 512.

- The variable $Y_{post1}$ shall be derived as specified in equation (31):

$$Y_{post1} = HDR_y[x][y] \quad (31)$$

- The variable $Y_{post2}$ shall be derived as specified in equation (32):

$$Y_{post2} = Clip3(0; maxSampleVal - 1; Y_{post1}) \quad (32)$$

- $U_{post2}$ and $V_{post2}$ shall be derived from $U_{post1}$ and $V_{post1}$ as specified in equation (33):

$$\begin{cases} U_{post2} = lutCC[Y_{post2}] \times U_{post1} \times maxCoeff \div m_3 \\ V_{post2} = lutCC[Y_{post2}] \times V_{post1} \times maxCoeff \div m_3 \end{cases} \quad (33)$$

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 (34):

$$\begin{bmatrix} R_1 \\ G_1 \\ B_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & m_0 \\ 1 & m_1 & m_2 \\ 1 & m_3 & 0 \end{bmatrix} \times \begin{bmatrix} 1 \\ U_{post2} \\ V_{post2} \end{bmatrix} \quad (34)$$

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 (35):

$$\begin{cases} R_2 = lutMapY[Y_{post2}] \times R_1) \\ G_2 = lutMapY[Y_{post2}] \times G_1) \\ B_2 = lutMapY[Y_{post2}] \times B_1) \end{cases} \quad (35)$$

- 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 (36):

$$\begin{cases} HDR_R[x][y] = 10\ 000 \times PQ_{EOTF}(R_2) \\ HDR_G[x][y] = 10\ 000 \times PQ_{EOTF}(G_2) \\ HDR_B[x][y] = 10\ 000 \times PQ_{EOTF}(B_2) \end{cases} \quad (36)$$

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 ]**.

These metadata variables 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 (37) up to and including (41):

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

$$\lambda = v\left(\frac{L_{HDR}}{L_{pdisp}}; L_{pdisp}\right) \quad (38)$$

$$scale = \frac{(\lambda-1)\times(\kappa+1)}{(\lambda+1)\times(\kappa-1)} \quad (39)$$

$$scaleHor = \frac{1-(1\div\lambda)}{1-(1\div\kappa)} \quad (40)$$

$$scaleVer = Max\left(\frac{1-\lambda}{1-\kappa}; 0\right) \quad (41)$$

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.

NOTE: $\kappa > 1$ for $L_{HDR} > L_{SDR}$.

### 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 (42) and (43):

$$TMWLO_{DA} = TMWLO \times Max(scaleHor; 0) \quad (42)$$

where:

- $scaleHor$ shall be taken from equation (40) in clause 7.3.2;
- $TMWLO$ 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.

$$TMBLO_{DA} = TMBLO \times Max(scaleHor; 0) \quad (43)$$

where:

- $scaleHor$ shall be taken from equation (40) in clause 7.3.2;
- $TMBLO$ 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 (44) up to and including (52):

$$MIDX = \frac{1-HGC}{SGC-HGC} \quad (44)$$

$$MIDX_{DA} = \frac{MIDX \times (SGC-1)}{2} \times (1 - scale) + MIDX \quad (45)$$

$$MIDY_{DA} = -1 \times MIDX_{DA} + MIDX \times (SGC + 1) \quad (46)$$

$$SGC_{DA} = \frac{MIDY_{DA}}{MIDX_{DA}} \quad (47)$$

where:

- $scale$ shall be taken from equation (39) in clause 7.3.2; and
- $SGC$ and $HGC$ shall be computed according to equations (15) and (16) in clause 7.2.3.1.5 using the unmodified metadata and using $L_{pdisp}$ equal to 100 cd/m².

NOTE: Due to the limitations on **highlightGain** and **shadowGain**, see clauses 6.3.5.4 and 6.3.5.5 of [1], $HGC \leq 0{,}5$; *expgain*>1 for $L_{HDR} > L_{pdisp}$, *exposure* ≥ 0,5and therefore $SGC > 0{,}5$.

$$para_{DA} = v(Abs(scale); L_{HDR}) \times para \quad (48)$$

where:

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

$$HGC_{DA} = \begin{cases} 0, & \text{if } MIDX_{DA} - 1 = 0 \\ Max\left(\frac{MIDY_{DA}-1}{MIDX_{DA}-1}\,;0\right), & otherwise \end{cases} \quad (49)$$

$$\mathbf{shadowGain_{DA}} = \left(\frac{SGC_{DA}}{\lambda} - 0{,}5\right) \times 4 \quad (50)$$

where:

- $\lambda$ is taken from equation (38), and
- **shadowGain**$_{\mathbf{DA}}$ 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.

$$\mathbf{highlightGain_{DA}} = HGC_{DA} \times 4 \quad (51)$$

where:

- **highlightGain**$_{\mathbf{DA}}$ 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.

$$\mathbf{midToneWidthAdjFactor_{DA}} = para_{DA} \times 2 \quad (52)$$

where:

- **midToneWidthAdjFactor**$_{\mathbf{DA}}$ 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 (53) up to and including (56).

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 (53):

$$x_{i_{HDR}} = BWAD_{inv}\left(TMO_{inv}(x_i)\right) \quad (53)$$

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];
- $x_{-1} = 0$, in case an additional inferred point (0; 0) is required, as specified in clause 6.3.5.9 in [1];
- $x_{\mathbf{tmOutputFineTuningNumVal}} = 1$, in case an additional inferred point (1; 1) is required, as specified in clause 6.3.5.9 in [1];
- $x_{i_{HDR}}$ is the scaled $x_i$, including if applicable the values for $i = -1$ and $i = \mathbf{tmOutputFineTuningNumVal}$, 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]); and
- $BWAD_{inv}(Y_{bw}) = Y_{pus}$ as computed by equation (54):

$$Y_{pus} = \left(1 - \frac{255 \times \mathbf{tmInputSignalWhiteLevelOffset}}{510} - \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset}}{2040}\right) \times Y_{bw} + \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset}}{2040} \quad (54)$$

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 (55):

$$x_{i_{DA}} = TMO_{DA}\left(BWAD_{DA}\left(x_{i_{HDR}}\right)\right) \quad (55)$$

where:

- $x_{i_{DA}}$ is the recomputed $x_i$, including if applicable the values for $i = -1$ and $i =$ **tmOutputFineTuningNumVal**, to be used for display adaptation in the block "Adjustment curve" in Figure 4 and clause 7.2.3.1.6;
- $BWAD_{DA}\left(Y_{pus}\right) = Y_{bw}$, 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 (42) to (43) 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 (56) using the scaling factor $scaleVer$ derived with equation (41) in clause 7.3.2:

$$y_{i_{DA}} = Min\left((y_i - x_i) \times scaleVer + x_{i_{DA}}\,;\ 1\right) \quad (56)$$

where:

- $scaleVer$ shall be taken from equation (41) in clause 7.3.2;
- $y_i$ 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];
- $y_{-1} = 0$, in case an additional inferred point (0; 0) is required, as specified in clause 6.3.5.9 in [1];
- $y_{\mathbf{tmOutputFineTuningNumVal}} = 1$, in case an additional inferred point (1; 1) is required, as specified in clause 6.3.5.9 in [1]; and
- $y_{i_{DA}}$ is the recomputed $y_i$, including if applicable the values for $i = -1$ and $i =$ **tmOutputFineTuningNumVal**, to be used for display adaptation in the block "Adjustment curve" in Figure 4 and clause 7.2.3.1.6.

In case the x-coordinate of the starting point of the list of pairs ($x_{i_{DA}}$; $y_{i_{DA}}$) is larger than zero, or if the x-coordinate of the ending point is smaller than one, the list is extended before it is used in the block "Adjustment curve" with one or two inferred points, such that the starting point of the list is always (0; 0) and the end point is always (1; 1).

# 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 1.
- In bitstreams conforming to the present document, the value of **original_picture_info_present_flag** may be equal to 0 or 1.

NOTE 1: The optional functionality specified in Annex I uses the information in the field **original_picture_max_luminance**.

- In bitstreams conforming to the present document, the value of **sl_hdr_extension_present_flag** shall be equal to 0.
- Decoders that comply with optional functionality specified in Annex I of the present document should process the value of **original_picture_max_luminance** if it is present in a bitstream.
- In bitstreams conforming to the present document, it is recommended that the **src_mdcv_info_present_flag** is equal to 1.
- In bitstreams conforming to the present document, if the **src_mdcv_info_present_flag** is equal to 0, an MDCV SEI message shall be present in the CLVS.
- In bitstreams conforming to the present document, if the **src_mdcv_info_present_flag** is equal to 1, the value of **original_picture_primaries**, if present, shall be equal to 1 in case the **src_mdcv_primaries_x**[ c ], **src_mdcv_primaries_y**[ c ], **src_mdcv_ref_white_x**, **src_mdcv_ref_white_y** indicate the Recommendation ITU-R 709 colour space, or 9 in case they indicate the Recommendation ITU-R 2020 colour space, or 12 in case they indicate the P3 colour space.
- In bitstreams conforming to the present document, if the **src_mdcv_info_present_flag** is equal to 0, the value of **original_picture_primaries**, if present, shall be equal to 1 in case the display primaries in the MDCV SEI message indicate the Recommendation ITU-R 709 colour space, or 9 in case they indicate the Recommendation ITU-R 2020 colour space, or 12 in case they indicate the P3 colour space.

NOTE 2: The two constraints above indicate that the original picture and the source picture, when different, have the same colour gamut.

- In bitstreams conforming to the present document, the value of **original_picture_min_luminance**, if present, shall be equal to 0.
- 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 **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 (informative): 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).

The HDR-to-SDR decomposition process generates an SDR backwards 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.

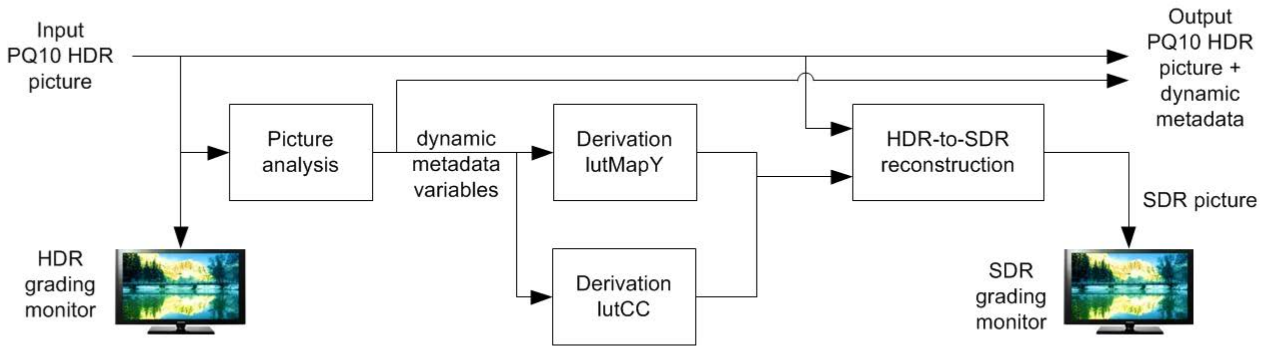



**Figure C.1: synopsis of the HDR-to-SDR decomposition process**

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.

Example values of **matrix_coefficient_value**[ i ] for all values of i can be found in Table F.1.

# 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.2020-2 [3] as specified by the variable **hdrPicColourSpace**), and is different from the colour gamut supported by the target presentation display (typically Recommendation ITU-R BT.709-6 [2] 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 Recommendations ITU-R BT.2020-2 [3] to BT.709-6 [2] is required in addition to the dynamic range mapping from HDR to HDR/SDR.

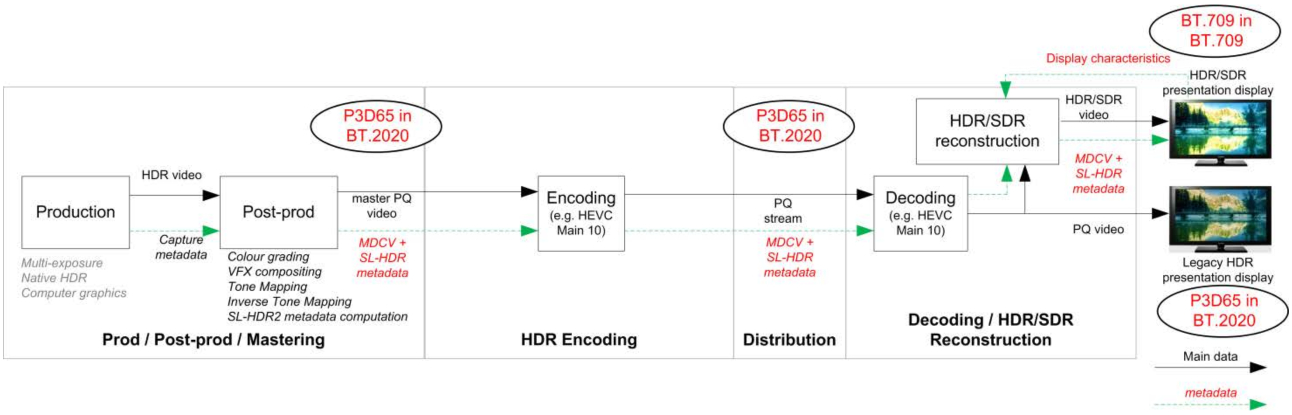



**Figure D.1: Example of use case requiring a gamut mapping**

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) SL-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, $Y'C'_bC'_r$ 4:4:4, $Y'C'_bC'_r$ 4:2:2 and $Y'C'_bC'_r$ 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, $Y'C'_bC'_r$ 4:4:4 and $Y'C'_bC'_r$ 4:2:2;
- at least 2 560 pixels on a line (3 840 or more recommended) for $Y'C'_bC'_r$ 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) |
| **packet_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 < **numReservedBytes**: i++) { | |
| **packet_reserved_byte** | 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 |

**packet_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.

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

NOTE: The number of additional bytes is determined from the value of **packet_length** and the size of the sl_hdr_info() field.

**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.3]):

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 $Y'C'_bC'_r$ 4:4:4 bit 0 (LSB) of all $C'_b$ samples are used.

For $Y'C'_bC'_r$ 4:2:2 bit 0 (LSB) of all $C'_b$ and $C'_r$ samples are used.

For $Y'C'_bC'_r$ 4:2:0 bit 0 (LSB) of all $C'_b$ 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 $Y'C'_bC'_r$ 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.

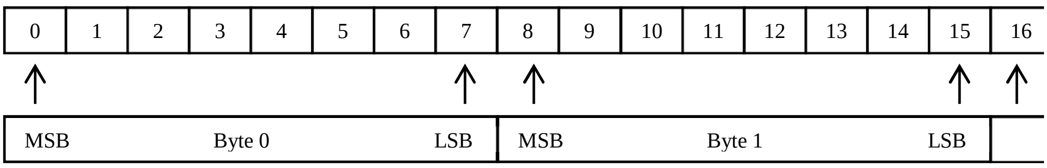



**Figure E.1: Mapping metadata on video**

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 $Y'C'_bC'_r$ 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 $Y'C'_bC'_r$ 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 E.2 and supported by the Sink device. If this bit is equal to 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, etc.) 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:

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

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 $Y'C'_bC'_r$-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<br>{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<br>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:

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

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

This clause proposes a recovery procedure for the value of the parameter **shadow_gain_control** that is applicable when MDCV SEI/ST 2086 messages are not available.

It is likely that at the service level information or for a specific workflow the value of **hdrDisplayMaxLuminance** is known. If it is not, **hdrDisplayMaxLuminance** can be set to the maximum luminance of the presentation display when available, otherwise it is arbitrarily set to a value of 1 000 cd/m². The latter value corresponds to the currently observed reference maximum display mastering luminance in most of the HDR markets. The value of **hdrDisplayMaxLuminance** that is obtained in this way can be input in the recovery procedure described in clause F.3.

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

Information on how ETSI TS 103 433 multi-part deliverable [i.7] 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 that do not specify carriage of SL-HDR2 metadata, a method to transport these metadata is described in Annex E.

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

In case $L_{pdisp}$ is anywhere inbetween 100 cd/m² (SDR maximum luminance) and the maximum luminance of the HDR grading monitor, **hdrDisplayMaxLuminance** (see clause 6.2.3 in [1]) in case of SL-HDR2, or **hdrOriginalMaxLuminance** (see clause I.2.3) in case of SL-HDR2+, here both indicated with $L_{HDR\_o}$, 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 or equal to $L_{pdisp\_min}$, or higher than $L_{pdisp\_max}$, see equations (H.1) and (H.2).

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

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

where:

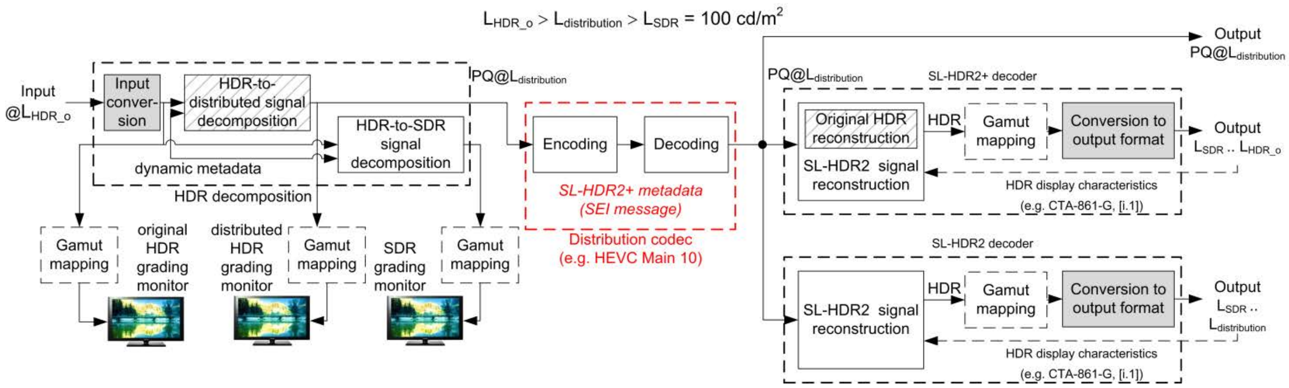
- $L_{HDR\_o}$ is the HDR mastering display maximum luminance**.**

# Annex I (informative): SL-HDR2+ and adaptive presentation display adaptation

## I.1 Introduction & system architecture

In the SL-HDR2 system, as specified in the present document up to Annex I, the encoder copies an HDR input stream to the distribution channel, but adds SL-HDR2 metadata to the HDR stream with which a decoder can recreate an SDR stream from the distributed HDR stream as specified by the encoder through the SL-HDR2 metadata.

The SL-HDR2+ system, as specified in Annex I and depicted in Figure I.1, is a backwards compatible extension to SL-HDR2.




NOTE: The two diagonally shaded blocks are additional to an SL-HDR2+ system compared to an SL-HDR2 system.

**Figure I.1: SL-HDR2+ system architecture overview**

Instead of outputting the HDR input stream unmodified to the distribution channel, an SL-HDR2+ encoder performs channel adaptation, i.e. it converts the original picture (HDR input to the encoder) first to a stream with a maximum luminance in between that of the original picture and the SDR signal before it is output to the distribution channel. The distributed stream resembles in all aspects an SL-HDR2 input stream to an SL-HDR2 decoder and can be decoded by an SL-HDR2 decoder. However, based on the value of a metadata parameter that is ignored by SL-HDR2 decoders, an SL-HDR2+ decoder is able to recreate the original picture and through display adaptation, any output with a maximum luminance in between that of the original picture and SDR.

This has as advantage that the stream distribution can be targeted to a lower maximum luminance that is supported by connected displays that do not support SL-HDR2 or SL-HDR2+ at the time of distribution, while an SL-HDR2+ decoder can create output streams that are optimized for all displays supporting a maximum luminance in the range of values higher than distributed up to the maximum luminance of the original picture and in the range of values lower than distributed down to SDR.

Although not shown in Figure I.1, the dynamic metadata in the block "HDR decomposition" in Figure I.1 may be generated by a process similar to the process "Picture analysis" as specified in Annex C. This may involve an additional grading monitor for the distributed HDR stream.

Similarly to SL-HDR2 systems and decoders, SL-HDR2+ systems may use gamut mapping as specified in Annex D, and SL-HDR2+ decoders may embed data on CE digital video interfaces as specified in Annex E.

Similarly to SL-HDR2 decoders, SL-HDR2+ decoders may use the error recovery mechanism as specified in Annex F, with the addition that in case SL-HDR2+ metadata (clause I.2) is lost or corrupted, the decoder may assume that the maximum luminance of the original input stream is the same as that of the distributed stream.

NOTE 1: In Annex I, parameters that are about the original picture have the subscript "orig", parameters that are about the stream that is channel adapted to the maximum luminance of the distributed stream have the subscript "dca", parameters that accompany the distributed stream have no subscript and parameters that are about a display adapted version have the subscript "DA".

NOTE 2: If the value of $L_{distr}$ would be set to the value of $L_{HDR\_o}$ in all formulas of Annex I, the resulting SL-HDR2+ system would behave identical to an SL-HDR2 system.

The remainder of Annex I is structured as follows:

- Clause I.2 specifies the use of clause 6 and SL-HDR2+ metadata.
- Clause I.3 specifies the SL-HDR2+ HDR-to-HDR/SDR signal reconstruction process (i.e. the SL-HDR2+ decoder).
- Clause I.4 specifies the SL-HDR2+ HDR-to-SDR decomposition principles and considerations (i.e. the SL-HDR2+ encoder).
- Clause I.5 specifies an enhanced method of display adaptation called display adaptation tuning. This method is applicable to both SL-HDR2 and SL-HDR2+.

# I.2 SL-HDR2+ dynamic metadata

## I.2.1 Introduction

Clause 6 specifies the metadata for an SL-HDR2 decoder, which in the present document is referred to as SL-HDR2 metadata. An SL-HDR2+ decoder uses the same SL-HDR2 metadata, although **hdrDisplayMaxLuminance** is used differently and is renamed to **hdrDistributedMaxLuminance** for SL-HDR2+ purposes. In addition to the SL-HDR2 metadata, an SL-HDR2+ decoder requires one extra item of metadata, **hdrOriginalMaxLuminance**. These two metadata items are defined in clause I.2.2 and clause I.2.3.

Clause I.2.4 specifies the recovery procedure for SL-HDR2+ streams when metadata is lost or corrupted.

## I.2.2 $L_{distr}$ - hdrDistributedMaxLuminance

An SL-HDR2+ decoder uses the SL-HDR2 metadata, but it treats this metadata as the metadata related to the maximum luminance of the distributed input stream, which is its input stream. In particular, an SL-HDR2+ decoder uses the value of **src_mdcv_max_mastering_luminance** (see clauses A.2.2.2, A.2.2.4 and A.2.3.3.4 of [1]) or **max_display_mastering_luminance** (see clause A.3.2 of [1]) not for the maximum display mastering luminance, i.e. the maximum luminance of the original picture, but as the maximum luminance of the distributed stream at its input. While both the maximum luminance of the original picture and of the distributed stream are the same and referred to by **hdrDisplayMaxLuminance** or $L_{HDR}$ in the specification of the SL-HDR2 functionality in the present document except Annex I, they are different for SL-HDR2+ and the latter maximum luminance is referred to by **hdrDistributedMaxLuminance** or $L_{distr}$ in the description of SL-HDR2+ in Annex I.

The mapping of metadata to the variable **hdrDistributedMaxLuminance** depends on the value of **src_mdcv_info_present_flag**.

- When **src_mdcv_info_present_flag** is equal to 0, **hdrDistributedMaxLuminance** is mapped from the MDCV SEI message syntax elements as specified in clause A.3.2, of [1], where **hdrDisplayMaxLuminance** is replaced by **hdrDistributedMaxLuminance**.
- When **src_mdcv_info_present_flag** is equal to 1, $L_{distr}$ is mapped as specified in equations (I.1) and (I.2).

$$\mathbf{hdrDistributedMaxLuminance} = Min\left(50 \times \left((\mathbf{src\_mdcv\_max\_mastering\_luminance} + 25)/50\right); 10\,000\right) \quad \text{(I.1)}$$

NOTE: Integer division with truncation of the result toward zero.

$L_{distr}$ and **hdrDistributedMaxLuminance** have the same value.

$$L_{distr} = \mathbf{hdrDistributedMaxLuminance} \quad \text{(I.2)}$$

SL-HDR2+ limits the values of $L_{distr}$ as specified by equation (I.3).

$$L_{SDR} < L_{distr} < L_{HDR\_o} \quad \text{(I.3)}$$

where:

- $L_{HDR\_o}$ is the maximum luminance of the original picture, see clause I.2.3; and
- $L_{SDR}$ is the maximum SDR luminance (100 cd/m$^2$).

### I.2.3 $L_{HDR\_o}$ - hdrOriginalMaxLuminance

Compared to an SL-HDR2 SEI message, an SL-HDR2+ SEI message contains three additional fields, **original_picture_max_luminance**, **original_picture_min_luminance** and **original_picture_primaries** (see clause A.2.2.2 and clause A.2.2.4 of [1]).

In contrast to an SL-HDR2 decoder, an SL-HDR2+ decoder uses the value of **original_picture_max_luminance**, if present in a stream, instead of **src_mdcv_max_mastering_luminance** (see clauses A.2.2.2, A.2.2.4 and A.2.3.3.4 of [1]) or **max_display_mastering_luminance** (see clause A.3.2 of [1]) for the maximum display mastering luminance, i.e. the maximum luminance of the original picture. While the maximum luminance of the original picture is referred to by **hdrDisplayMaxLuminance** or $L_{HDR}$ in clause 7, this is referred to with **hdrOriginalMaxLuminance** or $L_{HDR\_o}$, the maximum luminance of the original picture, in the description of SL-HDR2+ in Annex I.

In case the syntax element **original_picture_max_luminance** is not present in a stream, or in case it is present in a stream and has the value 0, the stream is an SL-HDR2 stream and is processed by a decoder as specified in clause 7.

Otherwise, the mapping of SL-HDR2+ metadata to the variable **hdrOriginalMaxLuminance** or $L_{HDR\_o}$ is performed according to equations (I.4), and (I.5).

$$\mathbf{hdrOriginalMaxLuminance} = Min\big(50 \times \big((\mathbf{original\_picture\_max\_luminance} + 25)/50\big); 10\,000\big) \quad \text{(I.4)}$$

NOTE: Integer division with truncation of the result toward zero.

$$L_{HDR\_o} = \mathbf{hdrOriginalMaxLuminance} \quad \text{(I.5)}$$

The syntax elements **original_picture_min_luminance** and **original_picture_primaries** are ignored by an SL-HDR2+ decoder conforming to the present document.

Therefore in the present document, the metadata specific to SL-HDR2+ consists of **original_picture_max_luminance**, which is mapped through equation (I.4) to the variable $L_{HDR\_o}$.

### I.2.4 Recovery from metadata loss or corruption

In case the SL-HDR2/SL-HDR2+ metadata is corrupt or got lost for an SL-HDR2+ stream, the decoder can treat the stream as if it is an SL-HDR2 stream and apply the recovery procedure of Annex F.

## I.3 SL-HDR2+ HDR-to-HDR/SDR signal reconstruction process

### I.3.1 Introduction

An SL-HDR2+ decoder resembles an SL-HDR2 decoder to a large degree. Basically, an SL-HDR2+ decoder adds a reconstruction of the original picture before the regular SL-HDR2 decoder. As such, most of clause 7 applies to an SL-HDR2+ decoder. Clause I.3 describes in detail how clause 7 applies to an SL-HDR2+ decoder and the extra functionality required for SL-HDR2+.

On a high level, the differences of an SL-HDR2+ decoder with an SL-HDR2 decoder are the following:

- An SL-HDR2+ decoder uses the value of **original_picture_max_luminance** (see clause A.2.2.2 and clause A.2.2.4 of [1]), if present, instead of **src_mdcv_max_mastering_luminance** (see clause A.2.2.2 and clause A.2.2.4 of [1]) for representing the maximum display mastering luminance of the original picture.
- An SL-HDR2+ decoder reconstructs the original metadata, i.e. the metadata determined in the SL-HDR2+ encoder for the original picture, from the distributed metadata, i.e. the metadata in the input stream of an SL-HDR2+ decoder.
- An SL-HDR2+ decoder reconstructs the luminance part of the original picture from the input stream before it invokes the luminance processing specified in clause 7 as applicable to an SL-HDR2 decoder. This may or may not involve the display adaptation to the maximum luminance, $L_{pdisp}$, of the presentation display as specified in clause 7.
- An SL-HDR2+ decoder also takes the reconstruction of the luminance part of the original picture from the input stream to the encoder into account for the computation of the colour correction table.

NOTE 1: An SL-HDR2+ decoder yields the same results as an SL-HDR2 decoder when the value of **original_picture_max_luminance** (see clause A.2.2.2 and clause A.2.2.4 of [1]) is the same as that of **src_mdcv_max_mastering_luminance** (see clause A.2.2.2 and clause A.2.2.4 of [1]) or **max_display_mastering_luminance** (see clause A.3.2 of [1]), when they are expressed in cd/m².

NOTE 2: A stream in which the syntax element **original_picture_max_luminance** (see clause A.2.2.2 and clause A.2.2.4 of [1]) is present and has the value 0 is an SL-HDR2 stream and is processed by a decoder as specified in clause 7.

Taking the above differences into account, Figure 3 and its description in clause 7.2.1 apply to an SL-HDR2+ decoder.

The present document does not support mapping table construction for **payloadMode** 1 for SL-HDR2+. Therefore, clauses 7.2.2, 7.2.3.3, and 7.2.3.4 do not apply to an SL-HDR2+ decoder.

The use of the other clauses in clause 7 and the new functionality required for an SL-HDR2+ decoder is detailed in clause I.3.2 on luminance mapping table construction, clause I.3.3 on colour correction table construction and clause I.3.4 on the HDR/SDR picture reconstruction from these mapping tables.

## I.3.2 SL-HDR2+ Luminance mapping table construction from variables (payloadMode 0)

### I.3.2.1 Introduction

The SL-HDR2+ luminance mapping table construction for **payloadMode** 0 derives a 1D look-up table $lutMapY$ from the luminance mapping variables as specified in clause 6.2.5 of [1].

In addition to the inputs mentioned in clause 7.2.3.1.1, this process takes as input:

- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (see clause I.2.3), and
- the maximum luminance of the distributed stream **hdrDistributedMaxLuminance** (see clause I.2.2).

The process generates as output:

- the luminance mapping look-up table $lutMapY$ of $maxSampleVal$ entries (clauses I.3.2.2 to I.3.2.16); and
- the luminance mapping to $L_{HDR\_o}$ look-up table $lutMapY_{HDR}$ of $maxSampleVal$ entries (clause I.3.2.17).

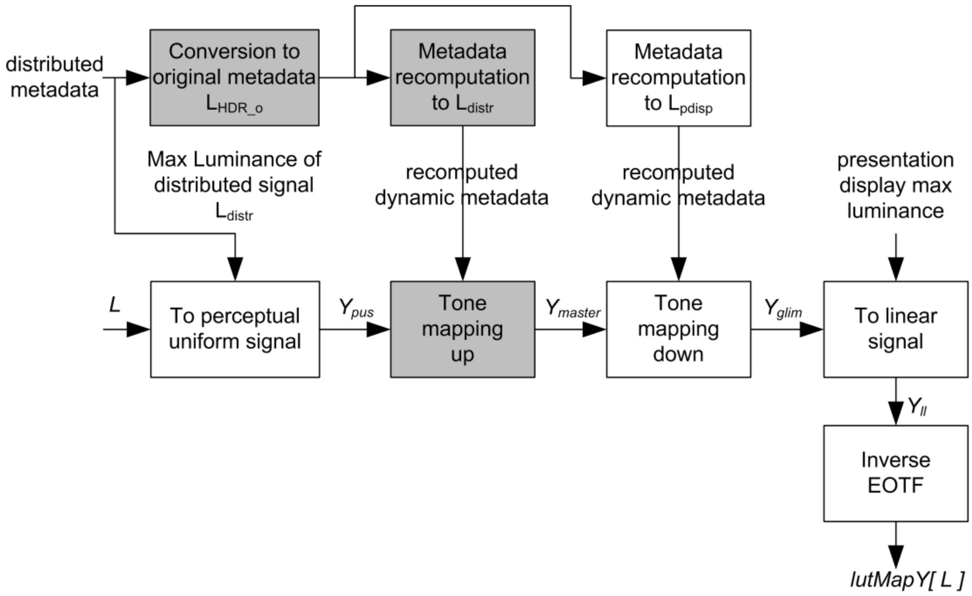
## I.3.2.2 Overview of the computation of lutMapY

The look-up table $lutMapY[\ L\ ]$, for luma values $L = 0..(\ maxSampleVal - 1\ )$, implements a tone mapping function. The SL-HDR2+ tone mapping process is shown in Figure I.2.

An SL-HDR2+ decoder does not treat its input stream as if it was the original picture, but reconstructs the luminance part of the original picture from the input stream before it invokes the luminance processing specified in clause 7. As part of this reconstruction, the original metadata need to be computed from the SL-HDR2 metadata in the input stream, which computation is based on $L_{HDR\_o}$ in the additional SL-HDR2+ metadata (see clause I.2).

In additions to the steps specified in clause 7.2.3.1.2, the following steps need to be taken:

- The reconstruction of the luminance part of the original picture is performed in the "Tone mapping up" block.
- The original metadata based on the maximum luminance of the original picture is computed from the distributed metadata in the block "Conversion to original metadata $L_{HDR\_o}$".
- The metadata to be used in the "Tone mapping up" block is computed from the original metadata that is based on the maximum luminance of the original picture in the "Metadata recomputation to $L_{distr}$" block (see clause I.2 for $L_{distr}$).




NOTE: The greyed blocks in Figure I.2 are required for SL-HDR2+ decoding, namely conversion of the metadata and reconstruction of the original picture. If the maximum luminance of the distributed signal, $L_{distr}$, would equal the maximum luminance of the original picture, $L_{HDR\_o}$, the greyed blocks "Conversion to original metadata $L_{HDR\_o}$", "Metadata recomputation to $L_{distr}$", and "Tone mapping up" in Figure I.2 would become the identity function and the process depicted in Figure I.2 would become identical to that of the SL-HDR2 decoder specified in clause 7.

**Figure I.2: Tone mapping process of an SL-HDR2+ decoder**

The blocks and their sub blocks shown in Figure I.2 are specified in detail in clauses I.3.2.3 to I.3.2.16.

The blocks "Tone mapping up" and "Tone mapping down" are illustrated in Figure I.3 and Figure I.4 respectively.

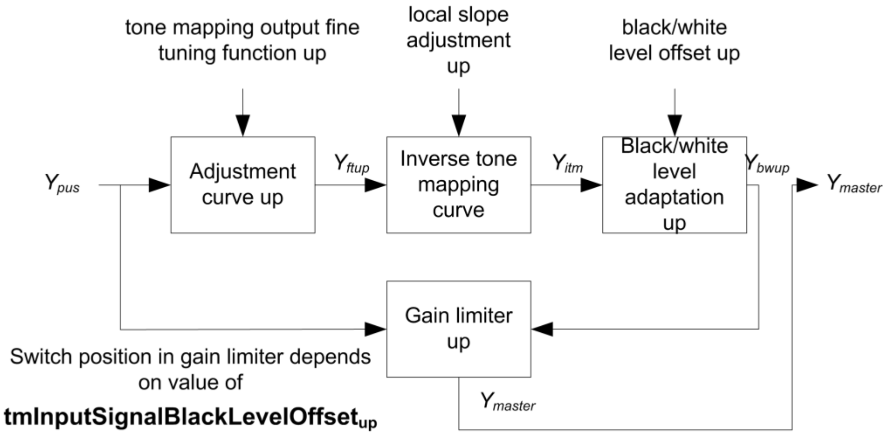



**Figure I.3: Tone mapping up process**

The blocks shown in Figure I.3 are specified in detail in clauses I.3.2.10 to I.3.2.13.

NOTE 1: The blocks shown in Figure I.3 are the same as the ones in clauses 7.2.3.1.4, 7.2.3.1.5, 7.2.3.1.6 and 7.2.3.1.7 of [1], except that other parameters are used.

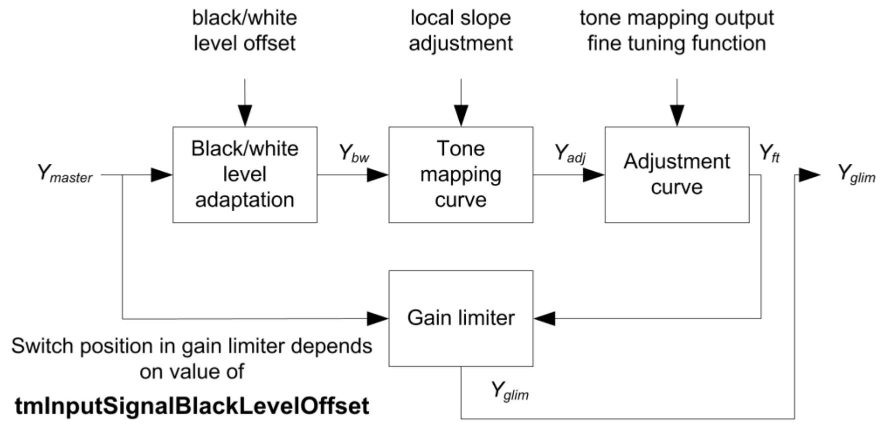



**Figure I.4: Tone mapping down process**

The blocks shown in Figure I.4 are specified in detail in clauses I.3.2.4 to I.3.2.7.

NOTE 2: The blocks shown in Figure I.4 are the same as the ones in clauses 7.2.3.1.4, 7.2.3.1.5, 7.2.3.1.6 and 7.2.3.1.7, except that other parameters are used.

## I.3.2.3 Block "To perceptual uniform signal"

The functionality of this block is the same as that specified in clause 7.2.3.1.3 with the following exceptions.

- Instead of the process input variable **hdrDisplayMaxLuminance**, the variable **hdrDistributedMaxLuminance** (clause I.2.2) is used, which is the maximum luminance of the distributed signal.
- $L_{distr}$ is used instead of $L_{HDR}$.

## I.3.2.4 Block "Black/white level adaptation"

The functionality of this block is the same as that specified in clause 7.2.3.1.4 with the following exception.

- The input variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]) are replaced by the variables **tmInputSignalBlackLevelOffset**$_{DA}$ and **tmInputSignalWhiteLevelOffset**$_{DA}$ as computed by the block "Metadata recomputation to $L_{pdisp}$" (see clause I.3.2.16).

## I.3.2.5 Block "Tone mapping curve"

The functionality of this block is the same as that specified in clause 7.2.3.1.5 with the following exceptions.

- The input variables **shadowGain**, **highlightGain**, **midToneWidthAdjFactor** from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]) are replaced by the variables **shadowGain**$_{DA}$, **highlightGain**$_{DA}$, **midToneWidthAdjFactor**$_{DA}$ as computed by the block "Metadata recomputation to $L_{pdisp}$" (see clause I.3.2.16).

- The input variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]) is replaced by the value of **hdrOriginalMaxLuminance** (see clause I.2.3).

- $L_{HDR\_o}$ is used instead of $L_{HDR}$.

## I.3.2.6 Block "Adjustment curve"

The functionality of this block is the same as that specified in clause 7.2.3.1.6 with the following exception.

- The **tmOutputFineTuningNumVal** number of input variables **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ] from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]) are replaced by the **tmOutputFineTuningNumVal**$_{DA}$ number of variables **tmOutputFineTuningX**$_{DA}$[ i ] and **tmOutputFineTuningY**$_{DA}$[ i ] as computed by the block "Metadata recomputation to $L_{pdisp}$" (see clause I.3.2.16).

## I.3.2.7 Block "Gain limiter"

The functionality of this block is the same as that specified in clause 7.2.3.1.7 with the following exceptions.

- The input variable **tmInputSignalBlackLevelOffset** from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]) is replaced by the variable **tmInputSignalBlackLevelOffset**$_{DA}$ as computed by the block "Metadata recomputation to $L_{pdisp}$" (see clause I.3.2.16).

- The input variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]) is replaced by the value of **hdrOriginalMaxLuminance** (see clause I.2.3).

- $L_{HDR\_o}$ is used instead of $L_{HDR}$.

## I.3.2.8 Block "To linear signal"

The functionality of this block is the same as that specified in clause 7.2.3.1.8.

## I.3.2.9 Block "Inverse EOTF"

The functionality of this block is the same as that specified in clause 7.2.3.1.9.

## I.3.2.10 Block "Adjustment curve up"

This is the first step of the tone mapping up process.

This process takes as inputs:

- the perceptual uniform value $Y_{pus}$; and

- all variables **tmOutputFineTuningNumVal**$_{up}$, **tmOutputFineTuningX**$_{up}$[ i ] and **tmOutputFineTuningY**$_{up}$[ i ] as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15).

The process generates as output:

- the corrected value $Y_{ftup}$.

In this block, the input signal $Y_{pus}$ is corrected by the inverse of the $ToneMappingOutputFineTuningFunction$ function $f_{ftlum}^{-1}()$, as specified by equation (I.6).

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

The list of points explicitly defining the inverse of the $ToneMappingOutputFineTuningFunction$ function consists of all pairs **tmOutputFineTuningY$_{up}$**[ i ], **tmOutputFineTuningX$_{up}$**[ i ] as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15).

NOTE: The x and y-values output by the block "Metadata recomputation to $L_{distr}$" have been swapped above in order to obtain the inverse of the $ToneMappingOutputFineTuningFunction$ function.

$$Y_{ftup} = \begin{cases} f_{ftlum}^{-1}(Y_{pus}), & 0 \leq Y_{adj} \leq 1 \\ Y_{pus}, & otherwise \end{cases} \quad (I.6)$$

## I.3.2.11 Block "Inverse tone mapping curve"

This process takes as inputs:

- the corrected value $Y_{ftup}$;
- the variables **shadowGain$_{up}$**, **highlightGain$_{up}$**, **midToneWidthAdjFactor$_{up}$** as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15);
- the variable **hdrDistributedMaxLuminance** (clause I.2.2); and
- the variable **hdrOriginalMaxLuminance** (clause I.2.3).

The process generates as output:

- the inverse tone-mapped value, in linear-light domain, $Y_{itm}$.

In this block, the input signal $Y_{ftup}$ is converted by an inverse tone mapping curve to the output signal $Y_{itm}$ according to equation (I.7).

$$Y_{itm} = TMO_{inv}(Y_{ftup}) \quad (I.7)$$

where:

- $TMO_{inv}(x)$ is defined by equations (6) up to and including (14) in clause 7.2.3.1.5 in [1], using the variables **shadowGain$_{up}$**, **highlightGain$_{up}$**, **midToneWidthAdjFactor$_{up}$** as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15) instead of **shadowGain**, **highlightGain**, and **midToneWidthAdjFactor**;
- using the value of the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3) or $L_{HDR\_o}$ for $L_{HDR}$; and
- using the value of the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2) or $L_{distr}$ for $L_{SDR}$.

## I.3.2.12 Block "Black/white level adaptation up"

This is the last step of the tone mapping up process.

This process takes as inputs:

- the inverse tone-mapped value, in linear-light domain, $Y_{itm}$; and
- the variables **tmInputSignalBlackLevelOffset$_{up}$**, **tmInputSignalWhiteLevelOffset$_{up}$** as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15).

The process generates as output:

- the stretched value $Y_{bwup}$.

In this block, the input signal $Y_{itm}$ is adapted by the black and white stretch in order to derive the output signal $Y_{bwup}$, as specified by equation (I.8) up to and including (I.10),

$$Y_{bwup} = BWAD_{inv}(Y_{itm}) = (1 - wlo - blo) \times Y_{itm} + blo \quad \text{(I.8)}$$

$$wlo = \frac{255 \times \mathbf{tmInputSignalWhiteLevelOffset_{up}}}{510} \quad \text{(I.9)}$$

$$blo = \frac{255 \times \mathbf{tmInputSignalBlackLevelOffset_{up}}}{2040} \quad \text{(I.10)}$$

## I.3.2.13 Block "Gain limiter up"

This process takes as inputs:

- the value $Y_{bwup}$ from clause I.3.2.12;
- the value $Y_{pus}$ from clause I.3.2.3;
- the variable **tmInputSignalBlackLevelOffset$_{up}$** as output by the block "Metadata recomputation to $L_{distr}$" (clause I.3.2.15);
- the variable **hdrDistributedMaxLuminance** (clause I.2.2); and
- the variable **hdrOriginalMaxLuminance** (clause I.2.3).

The process generates as output:

- the value $Y_{master}$

In this block, a choice is made between limiting $Y_{bwup}$ and passing it on unchanged, based on the value of the variable **tmInputSignalBlackLevelOffset$_{up}$**.

When the value of the variable **tmInputSignalBlackLevelOffset$_{up}$** is equal to 0, the output $Y_{master}$ of this block is the value $Y_{bwup}$.

When the value of the variable **tmInputSignalBlackLevelOffset$_{up}$** is not equal to 0, the value $Y_{master}$ is corrected for minimum gain based on the ratio of $L_{HDR\_o}$, the maximum luminance of the original picture, equal to the variable **hdrOriginalMaxLuminance** (clause I.2.3), and the maximum luminance of the SDR mastering display $L_{SDR}$ of 100 cd/m$^2$, as specified in equations (I.11) and (I.12),

$$Y_{master} = Min(Y_{bwup} ; Y_{pus} \div g) \quad \text{(I.11)}$$

$$g = v\left(\frac{0,1}{L_{SDR}}, L_{SDR}\right) \div v\left(\frac{1}{L_{HDR\_o}}, L_{HDR\_o}\right) \quad \text{(I.12)}$$

with:

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

## I.3.2.14 Block "Conversion to original metadata $L_{HDR\_o}$"

### I.3.2.14.1 Introduction

An SL-HDR2+ decoder uses the SL-HDR2 metadata, but it treats this metadata as the metadata related to the maximum luminance of the distributed input stream (source picture), which is its input stream.

An SL-HDR2+ decoder also requires the original metadata, i.e. the metadata related to the maximum luminance of the original picture, for the computation of the SL-HDR2+ luminance mapping table (see clause I.3.2) and the SL-HDR2+ colour correction table (see clause I.3.3).

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3);
- the luminance mapping variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ], from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]); and
- the colour correction adjustment variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ], from the structure colour_correction_adjustment( ) of the reconstruction metadata (clause 6.2.6 of [1]).

The process generates as output:

- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$**, **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ] and **tmOutputFineTuningY$_{orig}$**[ i ]; and
- the original colour correction adjustment variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ].

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the output variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$**, **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ], **tmOutputFineTuningY$_{orig}$**[ i ], **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] have the same value as the input variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ], **tmOutputFineTuningY**[ i ], **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] respectively. Otherwise, the computation of the original metadata is specified in clauses I.3.2.14.2, I.3.2.14.3, I.3.2.14.4 and I.3.2.14.5.

NOTE: Since the input of clauses I.3.2.14.3, I.3.2.14.4 and I.3.2.14.5 depends on the output of other clauses, the processes of clauses I.3.2.14.2, I.3.2.14.3, I.3.2.14.4 and I.3.2.14.5 should be executed in the order I.3.2.14.2, I.3.2.14.3, I.3.2.14.4 and finally I.3.2.14.5.

### I.3.2.14.2 Computation of original "Tone mapping curve" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3); and
- the luminance mapping variables **shadowGain**, **highlightGain** and **midToneWidthAdjFactor** from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]).

The process generates as output:

- the original luminance mapping variables **shadowGain$_{orig}$**, **highlightGain$_{orig}$** and **midToneWidthAdjFactor$_{orig}$**.

The output variable **midToneWidthAdjFactor$_{orig}$** has the same value as the input variable **midToneWidthAdjFactor**.

The output variable **shadowGain$_{orig}$** is computed from the input variable **shadowGain** according to equations (I.13) up to and including (I.22).

$$\mu = v\left(\frac{L_{distr}}{L_{SDR}}; L_{SDR}\right) \quad \text{(I.13)}$$

$$\kappa = v\left(\frac{L_{HDR\_o}}{L_{SDR}}; L_{SDR}\right) \quad \text{(I.14)}$$

$$\lambda = v\left(\frac{L_{HDR\_o}}{L_{distr}}; L_{distr}\right) \quad \text{(I.15)}$$

where:

- $v(x;y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3;
- $L_{SDR}$ is the SDR picture mastering display max luminance **sdrDisplayMaxLuminance**, which is taken as 100 cd/m²;
- $L_{distr}$ is the maximum luminance of the distributed signal equal to the variable **hdrDistributedMaxLuminance** (clause I.2.2); and
- $L_{HDR\_o}$ is the maximum luminance of the original picture, equal to the variable **hdrOriginalMaxLuminance** (clause I.2.3).

$$scale = \frac{(\lambda-1)\times(\kappa+1)}{(\lambda+1)\times(\kappa-1)} \quad \text{(I.16)}$$

NOTE 1: $\kappa > 1$ for $L_{HDR\_o} > L_{SDR}$; and $\lambda > 1$ for $L_{HDR\_o} > L_{distr}$; and $\kappa > \lambda$ for $L_{distr} > L_{SDR}$. Therefore, $scale > 0$ for $L_{HDR\_o} > L_{distr}$ and $scale < 1$ for $L_{distr} > L_{SDR}$.

$$SGC_{distr} = \mu \times \left(\frac{\textbf{shadowGain}}{4} + 0{,}5\right) \quad \text{(I.17)}$$

$$a_1 = 1 \quad \text{(I.18)}$$

$$b_1 = \frac{(SGC_{distr}-1)\times(scale+1)}{scale-1} \quad \text{(I.19)}$$

$$c_1 = -SGC_{distr} \quad \text{(I.20)}$$

$$SGC_{orig} = -\frac{b_1}{2\times a_1} + \frac{\sqrt{{b_1}^2-4\times a_1\times c_1}}{2\times a_1} \quad \text{(I.21)}$$

$$\textbf{shadowGain}_{\textbf{orig}} = Clip3\left(0;2;\left(\frac{SGC_{orig}}{\kappa} - 0{,}5\right)\times 4\right) \quad \text{(I.22)}$$

NOTE 2: The value of the variable **shadowGain$_{\textbf{orig}}$** is in the bounded range [0 to 2].

The output variable **highlightGain$_{\textbf{orig}}$** is computed from the input variable **highlightGain** according to equations (I.23) up to and including (I.30).

$$HGC_{distr} = \frac{\textbf{highlightGain}}{4} \quad \text{(I.23)}$$

$$SGC_{dca} = \frac{SGC_{orig}}{SGC_{distr}} \quad \text{(I.24)}$$

$$a_2 = \frac{(SGC_{dca}\times HGC_{distr}-SGC_{orig})\times(SGC_{orig}+1)}{(SGC_{dca}+1)} \quad \text{(I.25)}$$

$$b_2 = SGC_{orig} - HGC_{distr} - \frac{(SGC_{dca}\times HGC_{distr}-1)\times(SGC_{orig}+1)}{(SGC_{dca}+1)} \quad \text{(I.26)}$$

$$c_2 = HGC_{distr} - 1 \quad \text{(I.27)}$$

$$MIDX_{orig} = -\frac{b_2}{2\times a_2} + \frac{\sqrt{{b_2}^2-4\times a_2\times c_2}}{2\times a_2} \quad \text{(I.28)}$$

$$HGC_{orig} = \begin{cases} 0, & MIDX_{orig} = 1 \\ Max\left(0;\frac{MIDX_{orig}\times SGC_{orig}-1}{MIDX_{orig}-1}\right), & otherwise \end{cases} \quad \text{(I.29)}$$

$$\textbf{highlightGain}_{\textbf{orig}} = Clip3(0;2;HGC_{orig}\times 4) \quad \text{(I.30)}$$

where:

- $SGC_{orig}$ is the result from equation (I.21); and
- $SGC_{distr}$ is the result from equation (I.17).

NOTE 3: The value of the variable **highlighGain$_{orig}$** is in the bounded range [0 to 2].

### I.3.2.14.3 Computation of original "Black/white level adaptation" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3);
- the luminance mapping variables **tmInputSignalBlackLevelOffset**, and **tmInputSignalWhiteLevelOffset** from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]); and
- the original luminance mapping variables **shadowGain$_{orig}$**, **highlightGain$_{orig}$** and **midToneWidthAdjFactor$_{orig}$** as output by the process specified in clause I.3.2.14.2.

The process generates as output:

- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$** and **tmInputSignalWhiteLevelOffset$_{orig}$**.

The output variable **tmInputSignalBlackLevelOffset$_{orig}$** is computed from the input variable **tmInputSignalBlackLevelOffset** according to equations (I.31) and (I.34).

$$glim = v\left(\frac{0{,}1}{L_{SDR}}; L_{SDR}\right) \div v\left(\frac{1}{L_{HDR\_o}}; L_{HDR\_o}\right) \quad \text{(I.31)}$$

where:

- $v(x; y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3;
- $L_{SDR}$ is the SDR picture mastering display max luminance **sdrDisplayMaxLuminance**, which is taken as 100 cd/m²; and
- $L_{HDR\_o}$ is the maximum luminance of the original picture, equal to the variable **hdrOriginalMaxLuminance** (clause I.2.3).

$$scaleHor = \frac{(\lambda - 1)}{\lambda} \times \frac{\kappa}{(\kappa - 1)} \quad \text{(I.32)}$$

where:

- $\kappa$ and $\lambda$ are taken from equations (I.14) and (I.15) respectively.

NOTE 1: $\kappa > 1$ for $L_{HDR\_o} > L_{SDR}$ and $\lambda > 1$ for $L_{HDR\_o} > L_{distr}$.

$$TMBLO_{orig} = \mathbf{tmInputSignalBlackLevelOffset} \div Max(glim; 1 - scaleHor) \quad \text{(I.33)}$$

$$\mathbf{tmInputSignalBlackLevelOffset_{orig}} = TMBLO_{orig} \quad \text{(I.34)}$$

NOTE 2: The value of the output variable **tmInputSignalBlackLevelOffset$_{orig}$** is in the bounded range [0 to 1].

The output variable **tmInputSignalWhiteLevelOffset$_{orig}$** is computed from the input variables **tmInputSignalWhiteLevelOffset**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$** according to equations (I.35) up to and including (I.54).

$$HGC_{orig} = \frac{\mathbf{highlightGain_{orig}}}{4} \quad \text{(I.35)}$$

$$exposure = \frac{\mathbf{shadowGain_{orig}}}{4} + 0{,}5 \quad \text{(I.36)}$$

$$SGC_{orig} = \kappa \times exposure \quad \text{(I.37)}$$

where:

- $\kappa$ is taken from equation (I.14).

$$MIDX = \frac{1-HGC_{orig}}{SGC_{orig}-HGC_{orig}} \quad \text{(I.38)}$$

NOTE 3: Due to the limitations on **highlightGain$_{orig}$** and **shadowGain$_{orig}$**, see clause I.3.2.14.2, $HGC_{orig} \leq 0{,}5$; $\kappa$>1 for $L_{HDR\_o}$ > 100 cd/m², *exposure* ≥ 0,5 and therefore $SGC_{orig} > 0{,}5$ and $MIDX > 0$.

$$MIDX_{dca} = MIDX \times \left\{\frac{SGC_{orig}-1}{2} \times (1-scale) + 1\right\} \quad \text{(I.39)}$$

where:

- $scale$ is taken from equation (I.16).

$$MIDY_{dca} = MIDX \times \left\{\frac{SGC_{orig}-1}{2} \times (1+scale) + 1\right\} \quad \text{(I.40)}$$

$$SGC_{dca} = \frac{MIDY_{dca}}{MIDX_{dca}} \quad \text{(I.41)}$$

NOTE 4: Due to the limitations on $MIDX$ and $SGC_{orig}$, see note 3 above, and on *scale*, see note 1 seen below equation (I.16), $MIDX_{dca}$ and $MIDY_{dca}$ are always positive and therefore $SGC_{dca}$ is always positive.

$$HGC_{dca} = \begin{cases} 0, & MIDX_{dca} = 1 \\ Max\left(0; \frac{MIDY_{dca}-1}{MIDX_{dca}-1}\right), & otherwise \end{cases} \quad \text{(I.42)}$$

$$blo = \mathbf{tmInputSignalBlackLevelOffset_{orig}} \times scaleHor \times \frac{255}{2040} \quad \text{(I.43)}$$

where:

- $scaleHor$ is taken from equation (I.32).

$$para_{dca} = \begin{cases} 0, & HGC_{dca} = 0 \\ \frac{\mathbf{midToneWidthAdjFactor_{orig}}}{2} \times v\left(Abs(scale); L_{HDR\_o}\right), & otherwise \end{cases} \quad \text{(I.44)}$$

where:

- $scale$ is taken from equation (I.16); and
- $v(x;y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3.

$$xh = \frac{1-HGC_{dca}}{SGC_{dca}-HGC_{dca}} + \frac{para_{dca}}{2} \quad \text{(I.45)}$$

NOTE 5: $HGC_{dca}$ computed as $\frac{MIDY_{dca}-1}{MIDX_{dca}-1}$ in equation (I.42) becomes equal to $SGC_{dca}$ when $MIDY_{dca}$ becomes equal to $MIDX_{dca}$. $MIDY_{dca}$ becomes equal to $MIDX_{dca}$ when $scale$ becomes 0 or when $SGC_{orig}$ equals 1, which in its turn causes $MIDX$ and $MIDX_{dca}$ to become 1. $scale$ is unequal to 0, if $L_{distr}$ is unequal to $L_{HDR\_o}$. $MIDX_{dca}$ becoming 1 causes $HGC_{dca}$ to be set to 0 in equation (I.42), so causing $HGC_{dca}$ to become different from $SGC_{dca}$. This note also applies to equations (I.47) and (I.49).

$$xh_{dca} = HGC_{dca} \times xh + 1 - HGC_{dca} \quad \text{(I.46)}$$

$$xs = \frac{1-HGC_{dca}}{SGC_{dca}-HGC_{dca}} - \frac{para_{dca}}{2} \quad \text{(I.47)}$$

$$xs_{dca} = SGC_{dca} \times xs \quad \text{(I.48)}$$

$$a = \begin{cases} 0, & para_{dca} = 0 \\ -0{,}5 \times \frac{SGC_{dca} - HGC_{dca}}{para_{dca}}, & otherwise \end{cases}$$
$$b = \begin{cases} 0, & para_{dca} = 0 \\ \frac{1 - HGC_{dca}}{para_{dca}} + \frac{SGC_{dca} + HGC_{dca}}{2}, & otherwise \end{cases} \quad (I.49)$$
$$c = \begin{cases} 0, & para_{dca} = 0 \\ -\frac{\left((SGC_{dca} - HGC_{dca}) \times para_{dca} - 2 \times (1 - HGC_{dca})\right)^2}{8 \times (SGC_{dca} - HGC_{dca}) \times para_{dca}}, & otherwise \end{cases}$$

NOTE 6: If $para_{dca}$ equals 0, $xh_{dca}$ will equal $xs_{dca}$ and the values of $a$, $b$ and $c$ are not needed.

$$w = 1 - \mathbf{tmInputSignalWhiteLevelOffset} \times \frac{255}{510} \quad (I.50)$$

$$w_{dca\_unlim} = \begin{cases} 1 - (1 - w) \div HGC_{dca}, & w \geq xh_{dca} \\ -\frac{b}{2a} + \frac{\sqrt{b^2 - 4a \times (c - w)}}{2a}, & xs_{dca} < w < xh_{dca} \\ w \div SGC_{dca}, & otherwise \end{cases} \quad (I.51)$$

NOTE 7: $SGC_{dca}$ is always positive, see note 4 above. $HGC_{dca} = 0$ implies $MIDX_{dca}$ to be 1, which implies $SGC_{dca}$ to be 1, which causes $xh_{dca}$ and $xs_{dca}$ to become 1. The upper branch in equation (I.51) is therefore only taken when **tmInputSignalWhiteLevelOffset** is equal 0, but then equation (I.51) need not be computed.

$$w_{dca} = Min\left(1; w_{dca\_unlim}\right) \quad (I.52)$$

$$TMWLO_{orig} = \begin{cases} 0, & \mathbf{tmInputSignalWhiteLevelOffset} = 0 \\ \frac{(1 - w_{dca}) \times (1 - blo)}{1 - w_{dca} \times scaleHor} \times \frac{510}{255}, & otherwise \end{cases} \quad (I.53)$$

$$\mathbf{tmInputSignalWhiteLevelOffset_{orig}} = TMWLO_{orig} \quad (I.54)$$

NOTE 8: The value of the variable **tmInputSignalWhiteLevelOffset$_{orig}$** is in the bounded range [0 to 1].

### I.3.2.14.4 Computation of original "Adjustment curve" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3);
- the luminance mapping variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ], from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]);
- the original luminance mapping variables **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, and **midToneWidthAdjFactor$_{orig}$** as output by the process specified in clause I.3.2.14.2; and
- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$** and **tmInputSignalWhiteLevelOffset$_{orig}$** as output by the process specified in clause I.3.2.14.3.

The process generates as output:

- the original luminance mapping variables **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ] and **tmOutputFineTuningY$_{orig}$**[ i ].

The value of **tmOutputFineTuningNumVal$_{orig}$** is set to the value of **tmOutputFineTuningNumVal**.

The value of **tmOutputFineTuningY$_{orig}$**[ i ], is set to the value of **tmOutputFineTuningY**[ i ] for all i=0..( **luminanceMappingNumVal** - 1 ),

The value of **tmOutputFineTuningX$_{orig}$**[ i ] is set to 0 for all i=0.( **luminanceMappingNumVal** - 1 ) for which the value of **tmOutputFineTuningX**[ i ] equals 0.

The value of $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] is set to 1 for all i=0..( **luminanceMappingNumVal** - 1 ) for which the value of **tmOutputFineTuningX**[ i ] equals 1.

For all values of *i* for which no value of $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] has been computed, the value of $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ], is computed by the remainder of this clause.

NOTE 1: The process specified in this clause is the inverse of the process in clause I.4.5.4. However, the direct computation of that inverse requires the knowledge of the output $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] already during the computation. The computation of this inverse requires therefore some form of iteration. The remainder of this clause shows one of the many ways to do this.

For all *i* for which no value of $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] has been computed and for all 256 values of *j* in the interval [0..255], the process specified in clause I.4.5.4 is used to compute a look-up table *lutFtcX*, defined by:

$$x_{distr}[j] = lutFtcX[i][j \div 255] \quad \text{(I.55)}$$

where:

- $j \div 255$ is used as the input $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] for the process in clause I.4.5.4;
- $x_{distr}[j]$ is the corresponding output **tmOutputFineTuningX**[ i ] of the process in clause I.4.5.4; and
- using the value of **tmOutputFineTuningY**[ i ] as the input $\textbf{tmOutputFineTuningY}_{\textbf{orig}}$[ i ] to the process specified in clause I.4.5.4;
- using the input variables specified for this clause in the process specified in clause I.4.5.4.

For all values of *i* for which no value of $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] has been computed, the value of $j \div 255$ is selected as the output $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] of this clause, for which:

$$\delta[j] = Abs(lutFtcX[i][j \div 255] - \textbf{tmOutputFineTuningX}[\ i\ ]) \quad \text{(I.56)}$$

has the smallest value for all *j* in the interval [0..255].

NOTE 2: The process described above can be done using a binary search.

NOTE 3: The process in clause I.4.5.4 is partly based on the process specified in clause 7.3.5. The output variables $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{up}}$, $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{up}}$, $\textbf{shadowGain}_{\textbf{up}}$, $\textbf{highlightGain}_{\textbf{up}}$, and $\textbf{midToneWidthAdjFactor}_{\textbf{up}}$ of the process in clause I.3.2.15 can be used for the recomputed metadata required in equation (55) in clause 7.3.5.

### I.3.2.14.5 Computation of original "Saturation Gain" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3);
- the original luminance mapping variables $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}}$, $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{orig}}$, $\textbf{shadowGain}_{\textbf{orig}}$, $\textbf{highlightGain}_{\textbf{orig}}$, and $\textbf{midToneWidthAdjFactor}_{\textbf{orig}}$, as output by the processes in clause I.3.2.14.2 and in clause I.3.2.14.3;
- the original luminance mapping variables $\textbf{shadowGain}_{\textbf{orig}}$, $\textbf{highlightGain}_{\textbf{orig}}$, and $\textbf{midToneWidthAdjFactor}_{\textbf{orig}}$ as output by the process specified in clause I.3.2.14.2;
- the original luminance mapping variables $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}}$ and $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{orig}}$ as output by the process specified in clause I.3.2.14.3;
- the original luminance mapping variables $\textbf{tmOutputFineTuningNumVal}_{\textbf{orig}}$, $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] and $\textbf{tmOutputFineTuningY}_{\textbf{orig}}$[ i ] as output by the process specified in clause I.3.2.14.4; and
- the colour correction adjustment variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ], from the structure luminance_mapping_variables( ) of the reconstruction metadata (clause 6.2.5 of [1]).

The process generates as output:

- the original colour correction adjustment variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ].

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the output variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] have the same value as the input variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] for all i=0..( **saturationGainNumVal** - 1 ). Otherwise, they are computed as specified in the remainder of this clause.

The value of **saturationGainNumVal$_{orig}$** is set to the value of **saturationGainNumVal**.

For all values of $0 \leq i < \textbf{saturationGainNumVal}$, the value of **saturationGainX$_{orig}$**[ i ], is computed by equation (I.57) up to and including (I.59).

$$sx[i] = \textbf{saturationGainX}[i] \tag{I.57}$$

$$sx_{orig}[i] = \begin{cases} lutMapY_{HDR}\left[(maxSampleVal - 1) \times sx[i]\right], & sx[i] \leq invPQ(L_{distr}) \\ sx[i] \times \frac{invPQ(L_{HDR\_o})}{invPQ(L_{distr})}, & otherwise \end{cases} \tag{I.58}$$

where:

- $maxSampleVal$ is equal to $2^{10}$ i.e. 1 024;
- $lutMapY_{HDR}[L]$ is the lookup table specified in clause I.3.2.17, which is the inverse of the lookup table $PQDA[L]$ specified in clause I.4.5.5; and
- $invPQ(C)$ is the inverse of the PQ EOTF as specified by equations 5.1 and 5.2 of [6].

$$\textbf{saturationGainX}_{\boldsymbol{orig}}[i] = sx_{orig}[i] \tag{I.59}$$

NOTE 1: For all values of $0 \leq i < \textbf{saturationGainNumVal}$, the value of **saturationGainX$_{orig}$**[ i ], is in the bounded range [0 to 1].

For all values of $0 \leq i < \textbf{saturationGainNumVal}$, the value of **saturationGainY$_{orig}$**[ i ], is computed by equation (I.60) up to and including (I.63).

$$sy[i] = \textbf{saturationGainY}[i] \tag{I.60}$$

$$c\left(L_{HDR\_o}; L_{SDR}; L_{distr}\right) = 1 - \frac{invPQ(L_{distr}) - invPQ(L_{SDR})}{invPQ(L_{HDR\_o}) - invPQ(L_{SDR})} \tag{I.61}$$

where:

- $L_{SDR}$ is 100 cd/m²;

$$sy_{orig}[i] = \frac{\left(c(L_{HDR\_o}; L_{SDR}; L_{distr}) - 1\right) \times sy[i]}{2 \times c(L_{HDR\_o}; L_{SDR}; L_{distr}) \times sy[i] - 1} \tag{I.62}$$

$$\textbf{saturationGainY}_{\boldsymbol{orig}}[i] = sy_{orig}[i] \tag{I.63}$$

NOTE 2: For all values of $0 \leq i < \textbf{saturationGainNumVal}$, the value of **saturationGainY$_{orig}$**[ i ], is in the bounded range [0 to 1].

## I.3.2.15 Block "Metadata recomputation to $L_{distr}$"

This process takes as inputs:

- the maximum luminance of the distributed input stream **hdrDistributedMaxLuminance** (clause I.2.2);
- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3); and

- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$**, **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ] and **tmOutputFineTuningY$_{orig}$**[ i ] as output by the process specified in clause I.3.2.14.

The process generates as output:

- the luminance mapping variables **tmInputSignalBlackLevelOffset$_{up}$**, **tmInputSignalWhiteLevelOffset$_{up}$**, **shadowGain$_{up}$**, **highlightGain$_{up}$**, **midToneWidthAdjFactor$_{up}$**, **tmOutputFineTuningNumVal$_{up}$**, **tmOutputFineTuningX$_{up}$**[ i ] and **tmOutputFineTuningY$_{up}$**[ i ], adapted for the maximum luminance of the distributed input stream.

In this block, the metadata variables based on the maximum luminance of the original picture or recomputed to metadata variables based on the maximum luminance of the distributed input stream.

This recomputation is done as specified in clause 7.3, with the following adaptations.

- Clause 7.3.2 is used with the following adaptations.
  - The input variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]) is replaced by the value of **hdrOriginalMaxLuminance** (clause I.2.3).
  - $L_{HDR\_o}$ is used instead of $L_{HDR}$.
  - $L_{distr}$, or equally **hdrDistributedMaxLuminance** (clause I.2.2), is used instead of $L_{pdisp}$.
- The output variable **tmInputSignalWhiteLevelOffset$_{up}$** is taken as the output variable $TMWLO_{DA}$ of the recomputation for display adaptation as specified by clause 7.3.3 using **tmInputSignalWhiteLevelOffset$_{orig}$** from clause I.3.2.14.3 as input instead of **tmInputSignalWhiteLevelOffset**.
- The output variable **tmInputSignalBlackLevelOffset$_{up}$** is taken as the output variable $TMBLO_{DA}$ of the recomputation for display adaptation as specified by clause 7.3.3 using **tmInputSignalBlackLevelOffset$_{orig}$** from clause I.3.2.14.3 as input instead of **tmInputSignalBlackLevelOffset**.
- The "unmodified metadata" in clause 7.3.4 is the unmodified original metadata as computed by the block "Conversion to original metadata $L_{HDR\_o}$" (see clause I.3.2.14), in particular **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, and **midToneWidthAdjFactor$_{orig}$**.
- The output variables **shadowGain$_{up}$**, **highlightGain$_{up}$** and **midToneWidthAdjFactor$_{up}$** are computed by equations (50), (51) and (52) respectively as specified by clause 7.3.4 using "unmodified metadata" as specified above.
- The output variable **tmOutputFineTuningNumVal$_{up}$** is taken as the input variable **tmOutputFineTuningNumVal$_{orig}$** increased with the number of inferred points generated in the process specified in clause 7.3.5.

NOTE: **tmOutputFineTuningNumVal$_{orig}$** ≤ **tmOutputFineTuningNumVal$_{up}$** ≤ **tmOutputFineTuningNumVal$_{orig}$** + 2.

- The output variables **tmOutputFineTuningX$_{up}$**[ i ] and **tmOutputFineTuningY$_{up}$**[ i ] for i=0..( **tmOutputFineTuningNumVal$_{up}$** - 1 ) are taken as the output variables $x_{i_{DA}}$ and $y_{i_{DA}}$ from clause 7.3.5, using the original metadata output from clause I.3.2.14 as input instead of using the distributed metadata as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1].

### I.3.2.16 Block "Metadata recomputation to $L_{pdisp}$"

This process takes as inputs:

- the maximum luminance of the original picture **hdrOriginalMaxLuminance** (clause I.2.3);
- the original luminance mapping variables $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}}$, $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{orig}}$, $\textbf{shadowGain}_{\textbf{orig}}$, $\textbf{highlightGain}_{\textbf{orig}}$, $\textbf{midToneWidthAdjFactor}_{\textbf{orig}}$, $\textbf{tmOutputFineTuningNumVal}_{\textbf{orig}}$, $\textbf{tmOutputFineTuningX}_{\textbf{orig}}$[ i ] and $\textbf{tmOutputFineTuningY}_{\textbf{orig}}$[ i ] as output by the process specified in clause I.3.2.14; and
- the maximum luminance of the presentation display $L_{pdisp}$.

The process generates as output:

- the display adapted luminance mapping variables $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{DA}}$, $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{DA}}$, $\textbf{shadowGain}_{\textbf{DA}}$, $\textbf{highlightGain}_{\textbf{DA}}$, $\textbf{midToneWidthAdjFactor}_{\textbf{DA}}$, $\textbf{tmOutputFineTuningNumVal}_{\textbf{DA}}$, $\textbf{tmOutputFineTuningX}_{\textbf{DA}}$[ i ] and $\textbf{tmOutputFineTuningY}_{\textbf{DA}}$[ i ].

When the original metadata as computed in the block "Conversion to original metadata $L_{HDR\_o}$" is used unchanged in clause I.3, the resulting reconstruction process enables 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 I.3 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 $L_{HDR\_o}$. When $L_{HDR}$ is replaced by $L_{HDR\_o}$, the recommended range of values of $L_{pdisp}$ to perform display adaptation with can be computed as specified in Annex H.

For the adapted HDR picture generation, or display adaptation, certain original metadata needs to be recomputed before it can be used in the clauses I.3.2.4 to I.3.2.7. This is done as specified in clause 7.3, with the following adaptations.

- Clause 7.3.2 is used with the following exceptions.
  - The input variable **hdrDisplayMaxLuminance** (clause 6.2.3 of [1]) is replaced by the value of **hdrOriginalMaxLuminance** (clause I.2.3).
  - $L_{HDR\_o}$ is used instead of $L_{HDR}$.
- The output variable $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{DA}}$ is taken as the output variable $TMWLO_{DA}$ of the recomputation for display adaptation as specified by clause 7.3.3 using $\textbf{tmInputSignalWhiteLevelOffset}_{\textbf{orig}}$ from clause I.3.2.14.3 as input instead of **tmInputSignalWhiteLevelOffset**.
- The output variable $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{DA}}$ is taken as the output variable $TMBLO_{DA}$ of the recomputation for display adaptation as specified by clause 7.3.3 using $\textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}}$ from clause I.3.2.14.3 as input instead of **tmInputSignalBlackLevelOffset**.
- The "unmodified metadata" in clause 7.3.4 is the unmodified original metadata as computed by the block "Conversion to original metadata $L_{HDR\_o}$" (see clause I.3.2.14), in particular $\textbf{shadowGain}_{\textbf{orig}}$, $\textbf{highlightGain}_{\textbf{orig}}$, and $\textbf{midToneWidthAdjFactor}_{\textbf{orig}}$.
- The output variables $\textbf{shadowGain}_{\textbf{DA}}$ , $\textbf{highlightGain}_{\textbf{DA}}$ and $\textbf{midToneWidthAdjFactor}_{\textbf{DA}}$ are computed by equations (50), (51) and (52) respectively as specified by clause 7.3.4 using "unmodified metadata" as specified above.
- The output variable $\textbf{tmOutputFineTuningNumVal}_{\textbf{DA}}$ is taken as the input variable $\textbf{tmOutputFineTuningNumVal}_{\textbf{orig}}$ increased with the number of inferred points generated in the process specified in clause 7.3.5.

NOTE: $\textbf{tmOutputFineTuningNumVal}_{\textbf{orig}} \leq \textbf{tmOutputFineTuningNumVal}_{\textbf{DA}} \leq \textbf{tmOutputFineTuningNumVal}_{\textbf{orig}} + 2$.

- The **tmOutputFineTuningNumVal$_{DA}$** number of output variables **tmOutputFineTuningX$_{DA}$**[ i ] and **tmOutputFineTuningY$_{DA}$**[ i ] are taken as the output variables $x_{i_{DA}}$ and $y_{i_{DA}}$ from clause 7.3.5, using the original metadata output from clause I.3.2.14 as input instead of using the distributed metadata as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 in [1].

### I.3.2.17 The computation of lutMapY$_{HDR}$

The lookup table $lutMapY_{HDR}$ is used in the construction of the colour correction table, see clause I.3.3.

The computation of $lutMapY_{HDR}$ is done the same as the computation of $lutMapY$ as specified in clauses I.3.2.2 up to and including I.3.2.16, with $L_{pdisp}$ set to the value of $L_{HDR\_o}$ in the block "Metadata recomputation to $L_{pdisp}$" from clause I.3.2.16. This effectively means that the tone mapping down block in the tone mapping process of Figure I.2 is the identity function, i.e. it copies its input to its output.

## I.3.3 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 resembles the process specified in clause 7.2.3.2, with the luminance input to the derivation of the colour correction table adapted for the lower maximum luminance of the distributed stream.

This process takes as inputs:

- the variable **hdrOriginalMaxLuminance** (clause I.2.3);
- the variable **hdrDistributedMaxLuminance** (clause I.2.2);
- the SDR picture mastering display maximum luminance **sdrDisplayMaxLuminance** (clause 6.2.4 of [1]);
- the maximum luminance $L_{pdisp}$ of the presentation display (clause 7.2.1);
- the luminance mapping table $lutMapY_{HDR}$ of $maxSampleVal$ entries from $L_{distr}$ to $L_{HDR\_o}$ (clause I.3.2.17); and
- the original colour correction adjustment variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] (clause I.3.2.14.5).

The process generates as output:

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

The value of $lutCC$[ 0 ] is derived as specified in equation (I.64).

$$lutCC[0] = 0{,}125 \quad \text{(I.64)}$$

For each luma value $Y$ in 1..( $maxSampleVal$ - 1 ), $lutCC$[ $Y$] is derived as specified in equation (I.65).

$$lutCC[Y] = Min\left(lutCC[0]\,;\, \frac{1+modFactor_u \times {Y_l}^{2,4}}{Y_n \times \left(1+modFactor_d \times {Y_l}^{2,4}\right)} \times \frac{Max\left(R_{sgf} \div 255\,; R_{sgf} \times g_u(Y_l)\right)}{Max\left(R_{sgf} \div 255\,; R_{sgf} \times g_d(Y_l)\right)} \times \frac{1}{maxSampleVal-1}\right) \quad \text{(I.65)}$$

where:

- $Y_n = \frac{Y}{maxSampleVal-1}$;
- $Y_l = lutMapY_{HDR}[Y]$;

  where:

  - $lutMapY_{HDR}[Y]$ is specified in clause I.3.2.17;
- $modFactor_u = c\left(L_{HDR\_o}; L_{SDR}; L_{distr}\right)$, see equation (I.66);

- $g_u(Y_l) = f_{sgf}(Y_l) \times modFactor_u + (1 - modFactor_u) \div R_{sgf}$;
- $modFactor_d = c(L_{HDR\_o}; L_{SDR}; L_{pdisp})$, see equation (I.66);
- $g_d(Y_l) = f_{sgf}(Y_l) \times modFactor_d + (1 - modFactor_d) \div R_{sgf}$;
- the saturation gain function $f_{sgf}(\,)$ is derived from the piece-wise linear pivot points defined by the variables **saturationGainX$_{\mathbf{orig}}$**[ i ] and **saturationGainY$_{\mathbf{orig}}$**[ i ], for i=0..( **saturationGainNumVal$_{\mathbf{orig}}$** - 1 ), see clause 7.3 of [1]. When **saturationGainNumVal$_{\mathbf{orig}}$** is equal to 0, $f_{sgf}(\,) = 1 \div R_{sgf}$;
- $R_{sgf}$ = 2 in the present document.

The colour correction function $c(\mathrm{x};\mathrm{y};\mathrm{z})$ is derived as specified in equation (I.66).

$$c(\mathrm{x};\mathrm{y};\mathrm{z}) = 1 - \frac{invPQ(\mathrm{z}) - invPQ(\mathrm{y})}{invPQ(\mathrm{x}) - invPQ(\mathrm{y})} \quad \text{(I.66)}$$

where:

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

### I.3.4 HDR/SDR picture reconstruction from look-up tables and distributed HDR picture

The HDR/SDR reconstruction process for SL-HDR2+ is identical to the process specified in clause 7.2.4, except that the luminance mapping table $lutMapY$ as derived in clause I.3.2 is used and the colour correction table $lutCC$ as derived in clause I.3.3 is used.

## I.4 SL-HDR2+ HDR-to-SDR decomposition principles and considerations

### I.4.1 Introduction

The blocks "HDR-to-HDR reconstruction" and "HDR-to-SDR reconstruction" in Figure I.5 of the SL-HDR2+ HDR-to-SDR decomposition process aim at converting the input HDR to a PQ compatible version with a maximum luminance $L_{distr}$ lower than $L_{HDR\_o}$, the maximum luminance of the original picture, and an SDR compatible version. The process also uses side information such as the mastering display peak luminance, colour primaries, and the colour space in which the original input HDR, distributed HDR and SDR pictures are represented. In the present document, the HDR-to-HDR and HDR-to-SDR conversion operate without changes of the colour gamut or space. The original input HDR, distributed 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).

The decomposition processes generate an HDR signal $@L_{distr}$ and an SDR backwards compatible version from the input HDR signal, using an invertible process that guarantees a high quality reconstructed original HDR and SDR signal.

The process is summarized in Figure I.5 where the input HDR is PQ and has $L_{HDR\_o} > L_{distr}$, where $L_{HDR\_o}$ is the maximum luminance of the HDR mastering display and $L_{distr}$ is the maximum luminance of the distributed signal.

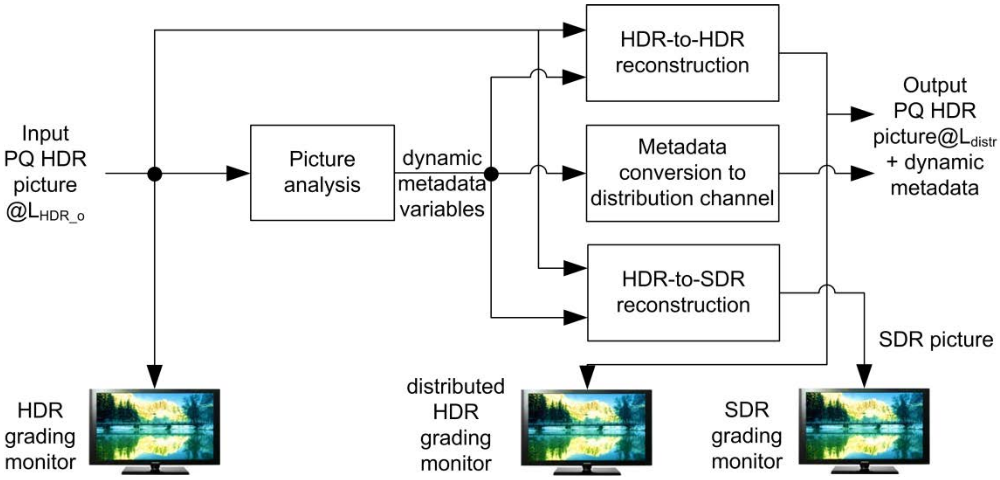



**Figure I.5: Synopsis of the HDR-to-SDR decomposition process for PQ input**

NOTE 1: The encoder shown in Figure I.5 would become an SL-HDR2 encoder, see Figure C.1, when $L_{HDR\_o}$ would become equal to $L_{distr}$. In that case, the blocks "HDR-to-HDR reconstruction" and "Metadata conversion to distribution channel" would become the identity function, i.e. they copy input to output.

The input PQ HDR picture is assumed to be graded on an HDR monitor. Only the HDR monitor is shown in Figure I.5 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.

From the input HDR 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 specified in clause C.3 of [1], in which case the block "HDR-to-SDR reconstruction" as well as the distribution HDR and SDR grading monitors are not required, or a process where a human grader observes the distributed HDR and SDR grading monitors while adjusting the metadata parameters for optimally graded distributed HDR and SDR pictures.

NOTE 2: The SDR and distributed HDR pictures cannot be adapted independently from one another by adjusting the dynamic metadata variables.

The blocks "Picture analysis", "HDR-to-SDR reconstruction", "HDR-to-HDR reconstruction" and "Metadata conversion to distribution channel" shown in Figure I.5 are specified in clauses I.4.2, I.4.3, I.4.4, and I.4.5 respectively.

The output of the decomposition process to the video encoder for e.g. video distribution is the output distributed HDR picture from the block "HDR-to-HDR reconstruction", together with the dynamic metadata variables as computed by the block "Metadata conversion to distribution channel". 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 and by clause I.2.

## I.4.2 Block "Picture analysis"

NOTE: This block is identical to the block "Picture analysis" in the SL-HDR2 HDR-to-SDR decomposition process, see Figure C.1.

This process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$; and
- the original input PQ HDR picture to the HDR-to-SDR decomposition process in clause I.4.1.

The process generates as output:

- the original luminance mapping variables **tmInputSignalBlackLevelOffset**$_{orig}$, **tmInputSignalWhiteLevelOffset**$_{orig}$, **shadowGain**$_{orig}$, **highlightGain**$_{orig}$, **midToneWidthAdjFactor**$_{orig}$, **tmOutputFineTuningNumVal**$_{orig}$, **tmOutputFineTuningX**$_{orig}$[ i ] and **tmOutputFineTuningY**$_{orig}$[ i ]; and

- the original colour correction adjustment variables **saturationGainNumVal**$_{orig}$, **saturationGainX**$_{orig}$[ i ] and **saturationGainY**$_{orig}$[ i ].

The determination of the output variables **tmInputSignalBlackLevelOffset**$_{orig}$, **tmInputSignalWhiteLevelOffset**$_{orig}$, **shadowGain**$_{orig}$, **highlightGain**$_{orig}$, **midToneWidthAdjFactor**$_{orig}$, **tmOutputFineTuningNumVal**$_{orig}$, **tmOutputFineTuningX**$_{orig}$[ i ] **tmOutputFineTuningY**$_{orig}$[ i ], **saturationGainNumVal**$_{orig}$, **saturationGainX**$_{orig}$[ i ] and **saturationGainY**$_{orig}$[ i ] is not specified in the present document, except for the limitations on their values.

The possible values of the output variables **tmInputSignalBlackLevelOffset**$_{orig}$, **tmInputSignalWhiteLevelOffset**$_{orig}$, **shadowGain**$_{orig}$, **highlightGain**$_{orig}$, **midToneWidthAdjFactor**$_{orig}$, **tmOutputFineTuningNumVal**$_{orig}$, **tmOutputFineTuningX**$_{orig}$[ i ] **tmOutputFineTuningY**$_{orig}$[ i ], **saturationGainNumVal**$_{orig}$, **saturationGainX**$_{orig}$[ i ] and **saturationGainY**$_{orig}$[ i ] are limited in the same way as specified in clause 6 of [1] for **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] **tmOutputFineTuningY**[ i ], **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] respectively.

## I.4.3 Block "HDR-to-SDR reconstruction"

NOTE: This block is identical to the combined blocks "HDR-to-SDR reconstruction", "Derivation lutMapY" and "Derivation lutCC" in the SL-HDR2 HDR-to-SDR decomposition process, see Figure C.1.

In case the SDR grading monitor is used, the block "HDR-to-SDR reconstruction" in Figure I.5 functions the same as an SL-HDR2 decoder as specified in clause 7.2, using dynamic metadata variables from the block "Picture analysis" in clause I.4.2 instead of the ones from the metadata structures as specified in clause 6, the value of $L_{HDR\_o}$ instead of $L_{HDR}$, and with the maximum luminance of the presentation display, $L_{pdisp}$, set to $L_{SDR}$, i.e. the recomputation of metadata as specified in clause 7.3 is not performed and the metadata values are used as determined in the block "Picture analysis".

## I.4.4 Block "HDR-to-HDR reconstruction"

The purpose of the block "HDR-to-HDR reconstruction" in Figure I.5 is to perform channel adaptation, i.e. tone mapping and colour correction from the maximum luminance of the HDR mastering display, $L_{HDR\_o}$, to the maximum luminance of the distributed signal, $L_{distr}$.

The block "HDR-to-HDR reconstruction" in Figure I.5 reuses SL-HDR2 technology. It functions the same as a decoder as specified in clause 7.2, using dynamic metadata variables from the block "Picture analysis" in clause I.4.2 instead of the ones from the metadata structures as specified in clause 6, the value of $L_{HDR\_o}$ instead of $L_{HDR}$, and using the display adaptation as specified in clause 7.3 with the maximum luminance of the presentation display, $L_{pdisp}$, set to $L_{distr}$, i.e. the maximum luminance of the distributed stream.

NOTE: In case $L_{distr}$ would be equal to $L_{HDR\_o}$, the output of this block would be identical to its input as is the case in an SL-HDR2 encoder, see Annex C.

## I.4.5 Block "Metadata conversion to distribution channel"

### I.4.5.1 Introduction

The metadata parameters that were used in the maximum luminance adaptation to $L_{distr}$ in the block "Encoder" (clause I.4.4) cannot be used directly as metadata on the distribution channel. Instead, these parameters are converted to other values, such that:

- SL-HDR2 decoders are able to reconstruct the SDR stream, and
- in addition to reconstruction of the SDR stream, SL-HDR2+ decoders are able to reconstruct the original picture (HDR stream input to the encoder) from the distributed stream, as well as perform display adaptation to any luminance between $L_{SDR}$ and $L_{HDR\_o}$.

NOTE 1: In case $L_{distr}$ would be equal to $L_{HDR\_o}$, the output of this block would be identical to its input as is the case in an SL-HDR2 encoder, see Annex C.

The "Metadata conversion to distribution channel" process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$;
- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$**, **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ] and **tmOutputFineTuningY$_{orig}$**[ i ] as output by the block "Picture analysis" (clause I.4.2); and
- the original colour correction adjustment variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] as output by the block "Picture analysis" (clause I.4.2).

The process generates as output:

- the maximum luminance of the distributed output stream **hdrDistributedMaxLuminance**;
- the maximum luminance of the original picture **hdrOriginalMaxLuminance**;
- the luminance mapping variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ], adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility;
- the colour correction adjustment variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ], adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility; and
- the mapping of the output metadata variables to SEI message syntax elements of Annex A.

The determination of the value of all other metadata variables specified in clause 6 of [1] for use in an SL-HDR2+ distributed stream as specified in Annex I is the same as that done by an SL-HDR2 encoder that does not use the extension specified in Annex I.

The output value **hdrDistributedMaxLuminance** is set to the value of the maximum luminance of the distributed output stream $L_{distr}$. The value of **hdrDistributedMaxLuminance** is mapped to the value of SEI message syntax elements **src_mdcv_min_mastering_luminance** and/or **max_display_mastering_luminance** (Annex A) in the same way as an SL-HDR1 encoder [1] maps **hdrDisplayMaxLuminance**.

The output value **hdrOriginalMaxLuminance** is set to the value of the maximum luminance of the original picture, $L_{HDR\_o}$. The value of **hdrOriginalMaxLuminance** is mapped to the value of SEI message syntax element **original_picture_max_luminance** (Annex A) as specified in equation (I.67):

$$\mathbf{original\_picture\_max\_luminance} = Min\left(50 \times \left((\mathbf{hdrOriginalMaxLuminance} + 25)/50\right); 10\,000\right) \quad \text{(I.67)}$$

The determination of the output values **shadowGain**, **highlightGain** and **midToneWidthAdjFactor** is specified in clause I.4.5.2.

The determination of the output values **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** is specified in clause I.4.5.3.

The determination of the output values **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ] is specified in clause I.4.5.4.

The determination of the output values **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] is specified in clause I.4.5.5.

NOTE 2: Since the input of clause I.4.5.4 depends on the output of clauses I.4.5.2 and I.4.5.3, the processes of clauses I.4.5.2 and I.4.5.3 should be executed before the process of clause I.4.5.4.

The output values **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ], **tmOutputFineTuningY**[ i ], **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] are mapped to the value of SEI message syntax elements (Annex A) in the same way as an SL-HDR1 encoder [1] maps these output values.

## I.4.5.2 Computation of distributed "Tone mapping curve" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$; and
- the original luminance mapping variables **shadowGain$_{orig}$**, **highlightGain$_{orig}$** and **midToneWidthAdjFactor$_{orig}$** as output by the block "Picture analysis" (clause I.4.2).

NOTE: The use of values of the input variable **highlightGain$_{orig}$** higher than **highlightGain$_{lim}$** leads to the clipping of the output variable **highlightGain** in this process, which in its turn leads to an SL-HDR2+ decoder not able to recreate the original input PQ HDR picture to the HDR-to-SDR decomposition process in clause I.4.1. The value of the input variable **highlightGain$_{orig}$** has therefore been limited to a maximum of **highlightGain$_{lim}$** by the process in the block "Picture analysis" (clause I.4.2).

The process generates as output:

- the luminance mapping variables **shadowGain**, **highlightGain** and **midToneWidthAdjFactor**, adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility.

The output variable **midToneWidthAdjFactor** has the same value as the input variable **midToneWidthAdjFactor$_{orig}$**.

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the output variables **shadowGain** and **highlightGain** have the same value as the input variables **shadowGain$_{orig}$** and **highlightGain$_{orig}$** respectively.

Otherwise, the output variables **shadowGain** and **highlightGain** are computed from the input variables **shadowGain$_{orig}$** and **highlightGain$_{orig}$** according to equations (I.68) up to and including (I.82).

$$\mu = v\left(\frac{L_{distr}}{L_{SDR}}; L_{SDR}\right) \tag{I.68}$$

$$\kappa = v\left(\frac{L_{HDR\_o}}{L_{SDR}}; L_{SDR}\right) \tag{I.69}$$

$$\lambda = v\left(\frac{L_{HDR\_o}}{L_{distr}}; L_{distr}\right) \tag{I.70}$$

where:

- $v(x; y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3;
- $L_{SDR}$ is the SDR picture mastering display max luminance, which is taken as 100 cd/m²;
- $L_{distr}$ the maximum luminance of the distributed input stream; and
- $L_{HDR\_o}$ the maximum luminance of the original picture.

$$scale = \frac{(\lambda-1)\times(\kappa+1)}{(\lambda+1)\times(\kappa-1)} \tag{I.71}$$

NOTE 1: $\kappa > 1$ for $L_{HDR\_o} > L_{SDR}$; and $\lambda > 1$ for $L_{HDR\_o} > L_{distr}$; and $\kappa > \lambda$ for $L_{distr} > L_{SDR}$. Therefore, $scale > 0$ for $L_{HDR\_o} > L_{distr}$ and $scale < 1$ for $L_{distr} > L_{SDR}$.

$$HGC_{orig} = \frac{\mathbf{highlightGain_{orig}}}{4} \tag{I.72}$$

$$exposure = \frac{\mathbf{shadowGain_{orig}}}{4} + 0{,}5 \tag{I.73}$$

$$SGC_{orig} = \kappa \times exposure \tag{I.74}$$

where:

- $\kappa$ is taken from equation (I.69).

$$MIDX = \frac{1-HGC_{orig}}{SGC_{orig}-HGC_{orig}} \quad \text{(I.75)}$$

NOTE 2: Due to the limitations on **highlightGain$_{orig}$** and **shadowGain$_{orig}$**, see clause I.3.2.14.2, $0 \leq HGC_{orig} \leq 0{,}5$; $\kappa > 1$ for $L_{HDR\_o} > 100$ cd/m²; $0{,}5 \leq exposure \leq 1$ and therefore $SGC_{orig} > 0{,}5$ and $MIDX > 0$.

$$MIDX_{dca} = MIDX \times \left\{\frac{SGC_{orig}-1}{2} \times (1-scale) + 1\right\} \quad \text{(I.76)}$$

NOTE 3: Due to the limitations on $MIDX$, $SGC_{orig}$ and $scale$, see note 1 and note 2 above, $MIDX_{dca}$ is always positive.

$$MIDY_{dca} = MIDX \times \left\{\frac{SGC_{orig}-1}{2} \times (1+scale) + 1\right\} \quad \text{(I.77)}$$

$$SGC = \frac{SGC_{orig} \times MIDX_{dca}}{MIDY_{dca}} \quad \text{(I.78)}$$

NOTE 4: Due to the limitations on $SGC_{orig}$ and $scale$, see note 1 and note 2 above, $MIDY_{dca}$ is always positive.

$$\mathbf{shadowGain} = Floor\left(127{,}5 \times Clip3\left(0;2;\left(\frac{SGC}{\mu} - 0{,}5\right) \times 4\right) + 0{,}5\right) \div 127{,}5 \quad \text{(I.79)}$$

NOTE 5: $\mu > 1$ for $L_{distr} > L_{SDR}$.

NOTE 6: The value of the variable **shadowGain** is in the bounded range [0 to 2] and is in multiples of $(2 \div 255)$.

$$HGC_{dca} = \begin{cases} 0, & MIDX_{dca} = 1 \\ Max\left(0;\frac{MIDY_{dca}-1}{MIDX_{dca}-1}\right), & otherwise \end{cases} \quad \text{(I.80)}$$

NOTE 7: The condition $MIDX_{dca} = 1$ also prevents a division by 0 in equations (I.91), (I.92) and (I.93) see the NOTE 3 seen below equation (I.91) in clause I.4.5.3.

$$HGC = \begin{cases} 0, & HGC_{dca} = 0 \\ \frac{HGC_{orig}}{HGC_{dca}}, & otherwise \end{cases} \quad \text{(I.81)}$$

$$\mathbf{highlightGain} = Floor(127{,}5 \times Clip3(0;2;HGC \times 4) + 0{,}5) \div 127{,}5 \quad \text{(I.82)}$$

NOTE 8: The value of the variable **highlightGain** is in the bounded range [0 to 2] and is in multiples of $(2 \div 255)$.

## I.4.5.3 Computation of distributed "Black/white level adaptation" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$; and
- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$** and **midToneWidthAdjFactor$_{orig}$** as output by the block "Picture analysis" (clause I.4.2).

The process generates as output:

- the luminance mapping variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset**, adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility.

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the output variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset** have the same value as the input variables **tmInputSignalBlackLevelOffset$_{orig}$** and **tmInputSignalWhiteLevelOffset$_{orig}$** respectively.

Otherwise, the output variable **tmInputSignalBlackLevelOffset**$_{\textbf{orig}}$ is computed from the input variable **tmInputSignalBlackLevelOffset** according to equations (I.83) up to and including (I.86).

$$glim = v\left(\frac{0,1}{L_{SDR}}; L_{SDR}\right) \div v\left(\frac{1}{L_{HDR\_o}}; L_{HDR\_o}\right) \quad \text{(I.83)}$$

where:

- $v(x; y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3;
- $L_{SDR}$ is the SDR picture mastering display max luminance, which is taken as 100 cd/m²; and
- $L_{HDR\_o}$ the maximum luminance of the original picture.

$$scaleHor = \frac{(\lambda - 1)}{\lambda} \times \frac{\kappa}{(\kappa - 1)} \quad \text{(I.84)}$$

where:

- $\kappa$ and $\lambda$ are taken from equations (I.69) and (I.70) respectively.

NOTE 1: $\kappa > 1$ for $L_{HDR\_o} > L_{SDR}$ and $\lambda > 1$ for $L_{HDR\_o} > L_{distr}$.

$$TMBLO_{distr} = \textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}} \times Max(glim; 1 - scaleHor) \quad \text{(I.85)}$$

$$\textbf{tmInputSignalBlackLevelOffset} = Floor(255 \times TMBLO_{distr} + 0,5) \div 255 \quad \text{(I.86)}$$

NOTE 2: The value of the output variable **tmInputSignalBlackLevelOffset**$_{\textbf{orig}}$ is in the bounded range [0 to 1] and is in multiples of ( $1 \div 255$).

If the value of $L_{distr}$ does not equal that of $L_{HDR\_o}$, the output variable **tmInputSignalWhiteLevelOffset**$_{\textbf{orig}}$ is computed from the input variables **tmInputSignalWhiteLevelOffset**, **shadowGain**$_{\textbf{orig}}$, **highlightGain**$_{\textbf{orig}}$, **midToneWidthAdjFactor**$_{\textbf{orig}}$ according to equations (I.87) up to and including (I.97).

$$blo = \textbf{tmInputSignalBlackLevelOffset}_{\textbf{orig}} \times scaleHor \times \frac{255}{2040} \quad \text{(I.87)}$$

$$wlo = \textbf{tmInputSignalWhiteLevelOffset}_{\textbf{orig}} \times scaleHor \times \frac{255}{510} \quad \text{(I.88)}$$

$$para_{dca} = \begin{cases} 0, & HGC_{dca} = 0 \\ \frac{\textbf{midToneWidthAdjFactor}_{\textbf{orig}}}{2} \times v\big(Abs(scale); L_{HDR\_o}\big), & otherwise \end{cases} \quad \text{(I.89)}$$

where:

- $HGC_{dca}$ is taken from equation (I.80);
- $scale$ is taken from equation (I.71); and
- $v(x; y)$ is taken from equations (2) and (3) in clause 7.2.3.1.3.

$$SGC_{dca} = \frac{MIDY_{dca}}{MIDX_{dca}} \quad \text{(I.90)}$$

where:

- $MIDX_{dca}$ is taken from equation (I.76) in clause I.4.5.2; and
- $MIDY_{dca}$ is taken from equation (I.77) in clause I.4.5.2.

$$xh = \frac{1 - HGC_{dca}}{SGC_{dca} - HGC_{dca}} + \frac{para_{dca}}{2} \quad \text{(I.91)}$$

where:

- $HGC_{dca}$ is taken from equation (I.80) in clause I.4.5.2.

NOTE 3: $HGC_{dca}$ computed as $\frac{MIDY_{dca}-1}{MIDX_{dca}-1}$ in equation (I.80) in clause I.4.5.2 becomes equal to $SGC_{dca}$ when $MIDY_{dca}$ becomes equal to $MIDX_{dca}$. $MIDY_{dca}$ becomes equal to $MIDX_{dca}$ when $scale$ becomes 0 or when $SGC_{orig}$ equals 1, which in its turn causes $MIDX$ and $MIDX_{dca}$ to become 1. $scale$ is unequal to 0, if $L_{distr}$ is unequal to $L_{HDR\_o}$. $MIDX_{dca}$ becoming 1 causes $HGC_{dca}$ to be set to 0 in equation (I.80) in clause I.4.5.2, so causing $HGC_{dca}$ to become different from $SGC_{dca}$. This note also applies to the following two equations.

$$xs = \frac{1-HGC_{dca}}{SGC_{dca}-HGC_{dca}} - \frac{para_{dca}}{2} \qquad \text{(I.92)}$$

$$a = \begin{cases} 0, & para_{dca} = 0 \\ -0{,}5 \times \frac{SGC_{dca}-HGC_{dca}}{para_{dca}}, & otherwise \end{cases}$$
$$b = \begin{cases} 0, & para_{dca} = 0 \\ \frac{1-HGC_{dca}}{para_{dca}} + \frac{SGC_{dca}+HGC_{dca}}{2}, & otherwise \end{cases} \qquad \text{(I.93)}$$
$$c = \begin{cases} 0, & para_{dca} = 0 \\ -\frac{\left((SGC_{dca}-HGC_{dca})\times para_{dca}-2\times(1-HGC_{dca})\right)^2}{8\times(SGC_{dca}-HGC_{dca})\times para_{dca}}, & otherwise \end{cases}$$

$$w = \frac{1-\mathbf{tmInputSignalWhiteLevelOffset_{orig}}\times\frac{255}{510}-blo}{1-wlo-blo} \qquad \text{(I.94)}$$

$$wlo_{dca} = \begin{cases} HGC_{dca}\times(1-w), & w \geq xh \\ 1-(a\times w^2+b\times w+c), & xs < w < xh \\ 1-SGC_{dca}\times w, & otherwise \end{cases} \qquad \text{(I.95)}$$

$$TMWLO_{distr} = wlo_{dca} \times \frac{510}{255} \qquad \text{(I.96)}$$

$$\mathbf{tmInputSignalWhiteLevelOffset} = Floor(255 \times Clip3(0;1;TMWLO_{distr}) + 0{,}5) \div 255 \qquad \text{(I.97)}$$

NOTE 4: The value of the variable **tmInputSignalWhiteLevelOffset** is in the bounded range [0 to 1] and is in multiples of $(1 \div 255)$.

### I.4.5.4 Computation of distributed "Adjustment curve" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$;
- the original luminance mapping variables **tmInputSignalBlackLevelOffset$_{orig}$**, **tmInputSignalWhiteLevelOffset$_{orig}$**, **shadowGain$_{orig}$**, **highlightGain$_{orig}$**, **midToneWidthAdjFactor$_{orig}$**, **tmOutputFineTuningNumVal$_{orig}$**, **tmOutputFineTuningX$_{orig}$**[ i ] and **tmOutputFineTuningY$_{orig}$**[ i ] as output by the block "Picture analysis" (clause I.4.2);
- the luminance mapping variables **shadowGain**, **highlightGain** and **midToneWidthAdjFactor**, adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility, as output by the process specified in clause I.4.5.2; and
- the luminance mapping variables **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset**, adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility, as output by the process specified in clause I.4.5.3.

The process generates as output:

- the luminance mapping variables **tmOutputFineTuningNumVal**, **tmOutputFineTuningX**[ i ] and **tmOutputFineTuningY**[ i ], adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility.

The value of **tmOutputFineTuningNumVal** is set to the value of **tmOutputFineTuningNumVal$_{orig}$**.

The value of **tmOutputFineTuningY**[ i ] is set to the value of **tmOutputFineTuningY$_{orig}$**[ i ] for all i=0..( **luminanceMappingNumVal$_{orig}$** - 1 ),

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the value of **tmOutputFineTuningX**[ i ] is set to the value of **tmOutputFineTuningX$_{orig}$**[ i ] for all i=0..( **luminanceMappingNumVal$_{orig}$** - 1 ). Otherwise, the values of **tmOutputFineTuningX**[ i ] are computed as specified in the remainder of this clause.

The value of **tmOutputFineTuningX**[ i ] is set to the value of **tmOutputFineTuningX$_{orig}$**[ i ] for all i=0..( **luminanceMappingNumVal$_{orig}$** - 1 ) for which the value of **tmOutputFineTuningY$_{orig}$**[ i ] equals 0 or 1.

For all values of *i* for which no value of **tmOutputFineTuningX**[ i ] has been computed using the above rule, the value of **tmOutputFineTuningX**[ i ], is computed by the following two steps.

In the first step, for all values of *i* for which no value of **tmOutputFineTuningX**[ i ] has been computed using the above rule, the value of $y_{i_{DA}}$ is computed as specified in clause 7.3.5, by:

- using the original luminance mapping variables as output by the block "Picture analysis" (clause I.4.2) as input;
- using the value of $L_{HDR\_o}$ for $L_{HDR}$; and
- using the value of $L_{distr}$ for $L_{pdisp}$.

NOTE: No inferred points are required in step 1 above.

In the second step, for all values of *i* for which no value of **tmOutputFineTuningX**[ i ] has been computed, the value of $y_{i_{DA}}$ is tone mapped from $L_{distr}$ to $L_{SDR}$ by the concatenation of the process "Black/white level adaptation" specified in clause 7.2.3.1.4 and the process "Tone mapping curve" specified in clause 7.2.3.1.5, by:

- using the value of $y_{i_{DA}}$ as the input $Y_{pus}$ in clause 7.2.3.1.4;
- using the newly computed channel metadata parameters **shadowGain**, **highlightGain**, **midToneWidthAdjFactor**, **tmInputSignalBlackLevelOffset** and **tmInputSignalWhiteLevelOffset**, from clauses I.4.5.2 and I.4.5.3 as input metadata;
- using the value of $L_{distr}$ for $L_{HDR}$ in clause 7.2.3.1.5; and
- using the value of $L_{SDR}$ (100 cd/m$^2$) for $L_{pdisp}$ in clause 7.2.3.1.5.

For all values of *i* for which no value of **tmOutputFineTuningX**[ i ] has been computed, the value of the output $Y_{adj}$ of the process specified in clause 7.2.3.1.5 is rounded to multiples of $(1 \div 255)$ and assigned to **tmOutputFineTuningX**[ i ] according to equation (I.98).

$$\textbf{tmOutputFineTuningX}[\text{ i }] = Floor(255 \times Y_{adj} + 0{,}5) \div 255 \quad \text{(I.98)}$$

## I.4.5.5 Computation of distributed "Saturation Gain" parameters

This process takes as inputs:

- the maximum luminance of the distributed input stream $L_{distr}$;
- the maximum luminance of the original picture $L_{HDR\_o}$; and
- the original colour correction adjustment variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] as output by the block "Picture analysis" (clause I.4.2).

The process generates as output:

- the colour correction adjustment variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ], adapted for the maximum luminance of the distributed input stream and SL-HDR2 backwards compatibility.

If the value of $L_{distr}$ equals that of $L_{HDR\_o}$, the output variables **saturationGainNumVal**, **saturationGainX**[ i ] and **saturationGainY**[ i ] have the same value as the input variables **saturationGainNumVal$_{orig}$**, **saturationGainX$_{orig}$**[ i ] and **saturationGainY$_{orig}$**[ i ] for all i=0..( **saturationGainNumVal$_{orig}$** - 1 ). Otherwise, they are computed as specified in the remainder of this clause.

The value of **saturationGainNumVal** is set to the value of **saturationGainNumVal$_{orig}$**.

For all values of $0 \leq i <$ **saturationGainNumVal**, the value of **saturationGainX**[ i ], is computed by equation (I.99) up to and including (I.101).

$$sx_{orig}[i] = \mathbf{saturationGainX_{orig}}[i] \quad \text{(I.99)}$$

$$sx[i] = \begin{cases} PQDA\left[(maxSampleVal - 1) \times sx_{orig}[i]\right], & sx_{orig}[i] \leq invPQ(L_{HDR\_o}) \\ sx_{orig}[i] \times \frac{invPQ(L_{distr})}{invPQ(L_{HDR\_o})}, & otherwise \end{cases} \quad \text{(I.100)}$$

where:

- $maxSampleVal$ is equal to $2^{10}$ i.e. 1 024;
- $PQDA[L]$ is the lookup table $lutMapY[\ L\ ]$ as specified in clause 7.2.3.1, using dynamic metadata variables from the block "Picture analysis" instead of the ones from the metadata structures as specified in clause 6, the value of $L_{HDR\_o}$ instead of $L_{HDR}$, and using the display adaptation as specified in clause 7.3 with the maximum luminance of the presentation display, $L_{pdisp}$, set to $L_{distr}$, i.e. the maximum luminance of the distributed stream; and
- $invPQ(C)$ is the inverse of the PQ EOTF as specified by equations 5.1 and 5.2 of [6].

NOTE 1: The lookup table $lutMapY[\ L\ ]$ to be used for $PQDA[L]$ is the same as the lookup table $lutMapY[\ L\ ]$ used in the block "HDR-to-HDR reconstruction" specified in clause I.4.4.

$$\mathbf{saturationGainX}[i] = Floor(255 \times sx[i] + 0{,}5) \div 255 \quad \text{(I.101)}$$

NOTE 2: For all values of $0 \leq i <$ **saturationGainNumVal**, the value of **saturationGainX**[ i ], is in the bounded range [0 to 1] and is a multiple of $(1 \div 255)$.

For all values of $0 \leq i <$ **saturationGainNumVal**, the value of **saturationGainY**[ i ], is computed by equation (I.102) up to and including (I.105).

$$sy_{orig}[i] = \mathbf{saturationGainY_{orig}}[i] \quad \text{(I.102)}$$

$$c(L_{HDR\_o}; L_{SDR}; L_{distr}) = 1 - \frac{invPQ(L_{distr}) - invPQ(L_{SDR})}{invPQ(L_{HDR\_o}) - invPQ(L_{SDR})} \quad \text{(I.103)}$$

where:

- $L_{SDR}$ is 100 cd/m².

$$sy[i] = \frac{sy_{orig}[i]}{1 + c(L_{HDR\_o}; L_{SDR}; L_{distr}) \times (2 \times sy_{orig}[i] - 1)} \quad \text{(I.104)}$$

$$\mathbf{saturationGainY}[i] = Floor(255 \times sy[i] + 0{,}5) \div 255 \quad \text{(I.105)}$$

NOTE 3: For all values of $0 \leq i <$ **saturationGainNumVal**, the value of **saturationGainY**[ i ], is in the bounded range [0 to 1] and is a multiple of $(1 \div 255)$.

# I.5 Display adaptation tuning

The display adaptation specified in clause 7 for SL-HDR2 can be tuned in order to accommodate to personal preferences by using tuned versions of a subset of the metadata input variables to the display adaptation specified in clause 7. This tuning is done by means of defining an alternate display adaptation tuning profile. With such an alternate profile, one can put more or less emphasis on desired areas of the tone mapping curve depending on the presentation display maximum luminance capability.

The display adaptation tuning described in this clause can also be used in combination with the display adaptation performed by the block "Tone mapping down" in Figure I.2 in SL-HDR2+. In that case, $L_{HDR}$ is replaced by $L_{HDR\_o}$ in this clause.

In order to be able to use the display adaptation tuning, the metadata input variables to the process specified in clause 7 or clause I.3.2.4, **tmInputSignalWhiteLevelOffset** and **tmInputSignalBlackLevelOffset**, as well as the metadata input variables to the process specified in clause 7 or clause I.3.2.5, **shadowGain**, **highlightGain**, and **midToneWidthAdjFactor**, need to be replaced by the output variables of this clause, **tunedTmInputSignalWhiteLevelOffset**, **tunedTmInputSignalBlackLevelOffset**, **tunedShadowGain**, **tunedHighlightGain**, and **tunedMidToneWidthAdjFactor** respectively.

This clause specifies the process to determine the tuned metadata input variables.

This process takes as inputs:

- the dynamic metadata, i.e. the luminance mapping variables **tmInputSignalBlackLevelOffset**, **tmInputSignalWhiteLevelOffset**, **shadowGain**, **highlightGain**, and **midToneWidthAdjFactor**, as stored in the structure luminance_mapping_variables( ) of the reconstruction metadata as specified in clause 6.2.5 of [1];
- the alternative metadata, i.e. **altTmInputSignalWhiteLevelOffset**, **altTmInputSignalBlackLevelOffset**, **altShadowGain**, **altHighlightGain**, and **altMidToneWidthAdjFactor** that are variables that have the same properties and range restrictions as their respective counterparts with the exception that they are local variables not received via the dynamic metadata channel;
- the maximum luminance of the presentation display, $L_{pdisp}$;
- the luminance limits $L_{min}$ and $L_{max}$, such that $L_{SDR} \leq L_{min} < L_{max} \leq L_{HDR}$;

  where:

  - $L_{HDR}$ is the maximum display mastering luminance from the variable **hdrDisplayMaxLuminance** in the structure hdr_characteristics( ) of the reconstruction metadata (clause 6.2.5 of [1]);
- $L_{SDR}$ is the maximum SDR luminance (100 cd/m$^2$); and
- the blending factor $\alpha$, such that $0 \leq \alpha \leq 1$.

The process generates as output:

- **tunedTmInputSignalWhiteLevelOffset**;
- **tunedTmInputSignalBlackLevelOffset**;
- **tunedShadowGain**;
- **tunedHighlightGain**; and
- **tunedMidToneWidthAdjFactor**.

The output variables of this process are computed from its inputs as specified by equations (I.106) up to and including (I.110).

$$\mathbf{tunedTmInputSignalWhiteLevelOffset} = \alpha \times \mathbf{altTmInputSignalWhiteLevelOffset} + (1 - \alpha) \times \mathbf{tmInputSignalWhiteLevelOffset} \quad \text{(I.106)}$$

$$\mathbf{tunedTmInputSignalBlackLevelOffset} = \alpha \times \mathbf{altTmInputSignalBlackLevelOffset} + (1-\alpha) \times \mathbf{tmInputSignalBlackLevelOffset} \quad \text{(I.107)}$$

$$\mathbf{tunedShadowGain} = \alpha \times \mathbf{altShadowGain} + (1-\alpha) \times \mathbf{shadowGain} \quad \text{(I.108)}$$

$$\mathbf{tunedHighlightGain} = \alpha \times \mathbf{altHighlightGain} + (1-\alpha) \times \mathbf{highlightGain} \quad \text{(I.109)}$$

$$\mathbf{tunedMidToneWidthAdjFactor} = \alpha \times \mathbf{altMidToneWidthAdjFactor} + (1-\alpha) \times \mathbf{midToneWidthAdjFactor} \quad \text{(I.110)}$$

where:

- the blending factor $\alpha$ is such that $0 \leq \alpha \leq 1$.

The blending factor $\alpha$ may be determined as a function of the maximum luminance of the presentation display in the following way.

An example value for $L_{min}$ may be $L_{min}$ = 100 cd/m$^2$.

An example value for $L_{max}$, may be $0{,}5 \times L_{HDR}$, or 50% of the maximum luminance of the HDR mastering display.

The luminance limits $L_{min}$ and $L_{max}$, are converted to their counterparts in the perceptual uniform domain according to equations (I.111) and (I.112).

$$v_{min} = v(\frac{L_{min}}{L_{HDR}}, L_{HDR}) \quad \text{(I.111)}$$

$$v_{max} = v(\frac{L_{max}}{L_{HDR}}, L_{HDR}) \quad \text{(I.112)}$$

where:

- $v(x, y)$ is taken from equations (2) and (3).

Finally, the blending factor $\alpha$ is computed according to equation (I.113).

$$\alpha = \begin{cases} 0, & v(\frac{L_{pdisp}}{L_{HDR}}, L_{HDR}) \leq v_{min} \\ 1, & v(\frac{L_{pdisp}}{L_{HDR}}, L_{HDR}) \geq v_{max} \\ \frac{v(\frac{L_{pdisp}}{L_{HDR}}, L_{HDR}) - v_{min}}{v_{max} - v_{min}}, & elsewhere \end{cases} \quad \text{(I.113)}$$

where:

- $L_{pdisp}$ is the maximum luminance of the presentation display, with $L_{SDR} \leq L_{pdisp} \leq L_{HDR}$.

NOTE 1: In the display adaptation tuning specified in this clause, the dynamic metadata from clause 6.2.5 of [1] are used as is for display adaptation to $L_{SDR}$. With increasing maximum luminance of the presentation display from $L_{SDR}$, the display adaptation from clause 7 is gradually changing from using the dynamic metadata from clause 6.2.5 of [1] to using the alternative metadata, where for display adaptation at $L_{max}$ and above, the alternative metadata is used as is.

NOTE 2: The alternative metadata may be derived from the dynamic metadata from clause 6.2.5 of [1].

# Annex J (informative): SL-HDR metadata indication for CMAF based applications

Annex H of ETSI TS 103 433-1 [1] applies to the present document.

# Annex K (informative):<br>Use of SL-HDR in DVB Services

Annex I of ETSI TS 103 433-1 [1] applies to the present document.

# Annex L (informative): Change History

| Date | Version | Information about changes |
|---|---|---|
| March 2017 | V0.0.1 | Early Draft |
| July 2017 | V0.0.2 | Stable Draft |
| September 2017 | V0.0.3 | Second Stable Draft |
| November 2017 | V0.0.4 | Draft for Approval |
| June 2019 | V1.1.2 | Early Draft |
| August 2019 | V1.1.3 | Stable Draft |
| November 2019 | V1.1.4 | Final Draft for Approval |

# History

| Document history | | |
|---|---|---|
| V1.1.1 | January 2018 | Publication |
| V1.2.1 | March 2020 | Publication |
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