

ICC Votable Proposal Submission

Headroom Adaptive Gain Curve Tag and Type

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1. Introduction

Summary

This proposal defines metadata that enables tone mapping a baseline image to an alternate image for varying amounts of HDR headroom. It replaces the adaptiveGainCurveTag tag and type approved in April 2025.

Problem to solve

Minimize image quality regressions when displaying HDR images on display devices with limited HDR capabilities or when transcoding HDR images to and from SDR in digital photography applications.

Solution

The proposal adds an optional tag type defining the Headroom Adaptive Gain Curve with new formulas and functions describing how this curve can be applied to the image for the purpose of tone mapping. The tag shall indicate whether the included Headroom Adaptive Gain Curve is image-specific and thus uniquely applicable to one image, or whether it can be used for tone mapping multiple images.

2. Result of this proposal acceptance

This proposal adds an optional version 4 tag (headroomAdaptiveGainCurveTag) and corresponding tag type headroomAdaptiveGainCurveType to ICC.1.

The proposed tag and type are optional; therefore, there are no required changes for CMMs. However, it is recommended that when the new tag is added to a profile, an A2B0 tag (and optionally A2B1 and/or A2B2 tags) is created based on the Headroom Adaptive Gain Curve and thus a backward-compatible approximation of tone mapping to SDR (target headroom of 0 stop) is provided.

3. Nature of this proposal

The adaptiveGainCurveTag and type were added to the ICC.1 specification on 17 April 2025. Subsequently, the algorithm was revised and published by SMPTE as SMPTE ST 2094-50:2026. It is now proposed that the adaptiveGainCurveTag and adaptiveGainCurveType be removed and replaced by the headroomAdaptiveGainCurveTag and headroomAdaptiveGainCurveType described in this document.

Accordingly, this proposal amends and supersedes the version 4.4.0.0 of the adaptiveGainCurveTag (ADGC) and its corresponding tag type (adaptiveGainCurveType).

This proposal does not impact ICC registries. The headroomAdaptiveGainCurveType contains the data and functions that describe how the Headroom Adaptive Gain Curve is applied to an image for HDR-to-SDR, SDR-to-HDR or HDR-to-HDR tone mapping with different target headroom levels. Additional information on implementing the headroomAdaptiveGainCurveTag and headroomAdaptiveGainCurveType is provided in informative annexes.

4. Votable Proposal

1.0 Normative References:

SMPTE specification ST 2094-50, “Dynamic metadata for color volume transform – Application #5”

1.1 headroomAdaptiveGainCurveTag

Tag signature: ‘HAGC’ (48414743h)

Permitted tag type: headroomAdaptiveGainCurveType

This tag defines a gain-based global tone mapping curve for either SDR or HDR images.

This tag may be present when the data colour space in the profile header is RGB, and the profile class in the profile header is Input, Display, or ColorSpace. The tag shall not be present for other data colour spaces or profile classes indicated in the profile header. When the headroomAdaptiveGainCurveTag is image-specific, the profile flags indicating that the profile is embedded and cannot be used independently of the colour data shall be set (bit position 0 = 1 and bit position 1 = 1).

1.2 headroomAdaptiveGainCurveType

Tag type signature: ‘hagc’ (68616763h)

The headroomAdaptiveGainCurveType specifies a gain-based global tone mapping method, adaptive to varying target headroom. It can define up to four gain curve functions, which can be used for different ranges of target headroom. The image resulting from applying a specific gain curve is referred to as an alternate image.

This tag type consists of a fixed header followed by a variable-size section of global tone mapping parameters, followed by variable-size sections applicable to alternate images, followed by parameters and gain curve control points data which is alternate image specific. All data included in the tag is processed by the Headroom Adaptive Gain Curve Function. An abbreviated description of the Headroom Adaptive Gain Curve Function is provided in annex 1 (informative). The detailed description is given in specification SMPTE ST 2094-50:2026.

1.2.1 headroomAdaptiveGainCurveType Header

The byte assignment and encoding of the header shall be as given in Table 1. The metadata defined as per specification SMPTE ST 2094-50:2026 begins at byte offset 12.

Table 1 — headroomAdaptiveGainCurveType header encoding

Byte position	Field length (bytes)	Content	Encoded as
0 to 3	4	‘hagc’ (68616763h) type signature	
4 to 7	4	Reserved, shall be set to 0	
8 to 11	4	Size of the SMPTE ST 2094-50:2026 metadata	uInt32Number
12	1	SMPTE ST 2094-50:2026 General Information: Application Version: 3 bits Minimum Application Version: 3 bits Reserved: 2 bits (zero)	uInt8Number

1.2.2 headroomAdaptiveGainCurveType Global Tone Mapping Parameters

The headroomAdaptiveGainCurveType header is followed by a section defining global tone mapping parameters which are applicable to all alternate images. The layout of the parameters shall be as given in Table 2.

Table 2 — Headroom Adaptive Gain Curve Global Tone Mapping Parameters Encoding

Byte position	Field length (bytes)	Content	Encoded as
0	1	Custom HDR Reference White flag: 1 bit Headroom Adaptive Tone Map flag: 1 bit Reserved: 6 bits (zero)	uInt8Number See 0.1.2.2 and 0.1.2.3
1 to 2 (if k ≠ 0)	2	Custom HDR Reference White	uInt16Number
k+1 to k+2	2	Baseline HDR Headroom (in log ₂ space)	uInt16Number
k+3	1	Reference White Tone Mapping flag: 1 bit Count of alternate images: 3 bits Gain Curve Chromaticities Mode: 2 bits Common Component Mixing flag: 1 bit Common Curve Parameters flag: 1 bit	uInt8Number
k+4 to k+19	16	Array of 8 custom chromaticity values	uInt16Number[8]

1.2.2.1 Custom HDR Reference White flag

The Custom HDR Reference White flag value shall be set to 1 when the tag contains a Custom HDR Reference White value.

1.2.2.2 Headroom Adaptive Tone Map flag

The Headroom Adaptive Tone Map flag value shall be set to 1 when headroom adaptive tone mapping is to be applied and the meta-data for tone mapping is included in the tag. When Headroom Adaptive Tone Map flag is set to 0, no headroom adaptive tone mapping metadata is provided and tone mapping is left at the discretion of the implementer.

1.2.2.3 Custom HDR Reference White

The Custom HDR Reference White value encoded as uInt16Number shall be converted to floating point representation using the following formula:

$$HDR\ Reference\ White_{float} = MIN(MAX(1, Custom\ HDR\ Reference\ White), 50000)/5.0$$

If no Custom HDR Reference White is specified, the value of HDR Reference White shall be 203.0.

1.2.2.4 Baseline HDR Headroom

The Baseline HDR Headroom value encoded as uInt16Number shall be converted to floating point representation using the following formula:

$$Baseline\ HDR\ Headroom_{float} = MIN(Baseline\ HDR\ Headroom, 60000)/10000.0$$

1.2.2.5 Reference White Tone Mapping flag

When the Reference White Tone Mapping flag = 0, the count of alternate images, Gain Curve Chromaticities Mode, Common Component Mixing flag and Common Curve Parameters flag shall be encoded explicitly in the bit fields of the same byte (byte k+3). When the Reference White Tone Mapping flag = 1, these bit fields shall be set to 0 in the binary data; their effective values shall not be read from the tag but instead derived on the decoding side as specified in Clause C.3.8 of specification SMPTE ST 2094-50, and no further records shall follow.

0.1.2.6 Count of alternate images

Alternate images are numbered from 0 to a maximum count of 4. Count value of 0 indicates that no tone mapping shall be performed and that the baseline image should be clamped to the target color volume.

0.1.2.7 Gain Curve Chromaticities Mode

If Gain Curve Chromaticities Mode = 0, chromaticity coordinates correspond to the colour primaries with a value of 2 in Table 2 in ITU-T H.273, i.e. primaries from Recommendation ITU-R BT.709-6.

If Gain Curve Chromaticities Mode = 1, chromaticity coordinates correspond to the colour primaries with a value of 12 in Table 2 in ITU-T H.273, i.e. primaries from specification SMPTE EG 432-1-2010, also known as DisplayP3.

If Gain Curve Chromaticities Mode = 2, chromaticity coordinates corresponds to the colour primaries with a value of 9 in Table 2 in ITU-T H.273, i.e. primaries from Recommendation ITU-R BT.2020-2.

If Gain Curve Chromaticities Mode = 3, chromaticity coordinates of the primaries are specified by an array of 8 values defining [x_R, y_R, x_G, y_G, x_B, y_B, x_w, y_w] Each element i of Array of 8 custom chromaticity values, encoded as uInt16Numbers, shall be converted to floating point representation using the following formula:

Chromaticity coordinate[i]_{float} = MIN(Chromaticity coordinate[i], 50000)/50000.0

1.1.2.8 Common Component Mixing flag

If Common Component Mixing flag is set to 1, signaling of component mixing mode (and Array of K coefficients when Component Mixing Type = 3) is specified only for the first alternate. Successive alternate images share the same component mixing mode.

1.1.2.9 Common Curve Parameters flag

If Common Curve Parameters flag is set to 1, signaling of:

Gain Curve Point Array Last Index (count-1):

PCHIP Slope flag

Array of control point X coordinates

is specified only for the first alternate. Successive alternate images share the same values for those gain curve function parameters.

1.1.3 headroomAdaptiveGainCurveType Alternate Image Tone Mapping Parameters

If the Reference White Tone Mapping flag is set to 0, the Headroom Adaptive Gain Curve Global Tone Mapping Parameters section is followed by sections specifying parameters for individual alternate images. Table 3 describes the layout of the parameters for the first alternate image. The layout of the sections for the images following the first image is identical to the first one, except when Common Component Mixing flag or Common Curve Parameters flag are set. If either one is set, the respective fields in the alternate image parameters are skipped and the ones specified for the first image shall be used.

As with the Global Tone Mapping Parameters, the length of the section varies depending on the content of specific fields, as indicated by variable offsets.

Table 3 — Alternate Image Gain Curve Data Encoding

Byte position	Field length (bytes)	Content	Encoded as
0 to 1	2	Alternate HDR Headroom (in log ₂ space)	uInt16Number

Byte position	Field length (bytes)	Content	Encoded as
2	1	Component Mixing Type: 2 bits The following bit fields are Non-Zero Coefficient Flags set to 1 when the corresponding coefficient is non-zero. Coefficient k_{Red} flag: 1 bit Coefficient k_{Green} flag: 1 bit Coefficient k_{Blue} flag: 1 bit Coefficient k_{Max} flag: 1 bit Coefficient k_{Min} flag: 1 bit Coefficient $k_{Component}$ flag: 1 bit	uInt8Number
3 to 3 + K*2-1, if K > 0	K*2	Array of K coefficients for Component Mixing Type = 3	uInt16Number[K]
M = 3+ K*2 if K > 0 otherwise M=3		Gain Curve Point Array Last Index (count-1): 5 bits (N) PCHIP Slope flag: 1 bit Reserved: 2 bits	uInt8Number
M+1 to M + (N+1)*2	(N+1)*2	Array of N+1 control point X coordinates	uInt16Number[N+1]
M+1+ (N+1)*2 to M + (N+1)*4	(N+1)*2	Array of N+1 control point Y coordinates	uInt16Number[N+1]
M + 1 + (N+1)*4 to M + (N+1)*6	(N+1)*2	Array of N+1 control point slope angles	uInt16Number[N+1]

1.1.3.1 Alternate HDR Headroom

Alternate HDR Headroom value encoded as uInt16Number shall be converted to floating point representation using the same formula as for Baseline HDR Headroom, i.e.:

$$\text{Alternate HDR Headroom}_{float} = \text{MIN}(\text{Alternate HDR Headroom}, 60000)/10000.0$$

1.1.3.2 Component Mixing Type

Component Mixing Type value shall be in the range from 0 to 3.

Informative annex 1 describes specific formulations for each of the Component Mixing Types.

1.1.3.2.1 Component Mixing Coefficients

If Component Mixing Type is equal to 3, coefficient values encoded as uInt16Numbers shall be converted to floating point representation using the following formula:

$$\text{value}_{float} = \text{MIN}(\text{value}, 50000)/50000.0$$

Non-zero value of a parameter should be indicated by a corresponding coefficient flag set to 1. If a coefficient value is zero, the corresponding flag should be set to 0 and the value excluded from the array of values. Therefore the size of the array of coefficients for Component Mixing Type = 3 must be equal to the count of non-zero Coefficient Flags. The order of coefficients is as follows:

k_{Red} , k_{Green} , k_{Blue} , k_{Max} , k_{Min} , $k_{Component}$

1.1.3.4 Maximum Index of control points

Control points are numbered from 0 to Maximum Index of Control Points, thus this entry is equal to the count of control points - 1.

The Maximum index of control points shall be greater than or equal to 0 and less than or equal to 31.

1.1.3.5 PCHIP (Piecewise Cubic Hermite Interpolating Polynomial) Slope flag

If PCHIP Slope flag is set to 1, control point slope angles are not included in the metadata and the control point M slope shall be calculated as described in Clause C.3.9 of specification SMPTE ST 2094-50:2026.

0.1.3.5 Control point X coordinates

Control point X coordinate values encoded as uInt16Numbers shall be converted to floating point representation using the following formula:

$$X_{float} = MIN(X, 64000)/1000.0$$

0.1.3.6 Control point Y coordinates

Control point Y coordinate values encoded as uInt16Numbers shall be converted to floating point representation using the following formula:

$$Y_{float} = s * MIN(Y, 60000)/10000.0$$

Where s = 1 if Baseline HDR Headroom < alternate headroom and s = -1 otherwise.

0.1.3.9 Control point slope angles

When PCHIP Slope flag is set to 0, control point Y coordinates are followed by control point θ slope angle values, encoded as uInt16Numbers, which shall be converted to control point M slope (in floating point representation) using the following formula:

$$M_{float} = \tan((MIN(MAX(I, \theta), 35999) - 18000) * \pi / 36000)$$

Annex 1 Headroom Adaptive Gain Curve Function (informative)

1.1 General

The metadata in the headroomAdaptiveGainCurveTag is used to calculate alternate image values according to the Headroom Adaptive Gain Curve Function.

1.2 Headroom Adaptive Gain Curve Function

The Headroom Adaptive Gain Curve Function comprises three steps:

1. an input component mixing
2. a gain evaluator
3. an output evaluator

Input Component Mixing

The general mathematical formulation of the input component mixing is expressed as follows:

$$\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} = R \times k_{red} + G \times k_{green} + B \times k_{blue} + RGB_{Max} \times k_{max} + RGB_{Min} \times k_{min} + \begin{bmatrix} R_{inp} \\ G_{inp} \\ B_{inp} \end{bmatrix} \times k_{component}$$

Where:

- R, G and B represent the value of the Red, Green and Blue component respectively.
- $RGB_{Max} = MAX(R_{inp}, G_{inp}, B_{inp})$ is the maximum color component.
- $RGB_{Min} = MIN(R_{inp}, G_{inp}, B_{inp})$ is the minimum color component.

The mixing coefficients are defined as follows:

- k_{Red} represents the weighting of the color component Red
- k_{Green} represents the weighting of the color component Green

- k_{Blue} represents the weighting of the color component Blue
- k_{Max} represents the weighting of the maximum color component
- k_{Min} represents the weighting of the minimum color component
- $k_{Component}$ represents the weighting of each color component of {Red, Green, Blue}

The Component Mixing Type identifies uniquely one of four specific mixing:

- Component Mixing Type = 0
 - $k_{Red} = k_{Green} = k_{Blue} = k_{Min} = k_{Component} = 0, k_{Max} = 1.0$
 - $\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} = \begin{bmatrix} RGB_{Max} \\ RGB_{Max} \\ RGB_{Max} \end{bmatrix}$
- Component Mixing Type = 1
 - $k_{Red} = k_{Green} = k_{Blue} = k_{Min} = k_{Max} = 0, k_{Component} = 1.0$
 - $\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} = \begin{bmatrix} R_{inp} \\ G_{inp} \\ B_{inp} \end{bmatrix}$
- Component Mixing Type = 2
 - $k_{Red} = k_{Green} = k_{Blue} = 1.0/6.0, k_{Min} = 0, k_{Max} = 1.0/2.0, k_{Component} = 0$
 - $\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} = \begin{bmatrix} \frac{(R_{inp}+G_{inp}+B_{inp})}{6.0} + \frac{RGB_{Max}}{2.0} \\ \frac{(R_{inp}+G_{inp}+B_{inp})}{6.0} + \frac{RGB_{Max}}{2.0} \\ \frac{(R_{inp}+G_{inp}+B_{inp})}{6.0} + \frac{RGB_{Max}}{2.0} \end{bmatrix}$
- Component Mixing Type = 3
 - $p_{Sum} = k_{Red} + k_{Green} + k_{Blue} + k_{Min} + k_{Max} + k_{Component}$
 - $\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} = \frac{\begin{bmatrix} R \times k_{red} + G \times k_{green} + B \times k_{blue} + RGB_{Max} \times k_{max} + RGB_{Min} \times k_{min} + \begin{bmatrix} R_{inp} \\ G_{inp} \\ B_{inp} \end{bmatrix} \times k_{component} \end{bmatrix}}{p_{sum}}$

Notes:

1. $k_{Red}, k_{Green}, k_{Blue}, k_{Min}, k_{Max}, k_{Component}$ floating point representation as computed in Section 0.1.3.4 shall be in the range of [0.0, 1.0].
2. When $k_{Component} = 0$, the Gain Evaluator returns the same result for all three components.
3. p_{Sum} cannot be equal to 0.

Gain Evaluator

The gain evaluator processes a set of ordered control points which are represented by input, output and slope. The mathematical formulation of the gain evaluator is expressed as a piecewise cubic curve $f(x)$ where each segment is defined by a beginning control point $\{x_i, y_i, m_i\}$ and ending control point $\{x_{i+1}, y_{i+1}, m_{i+1}\}$, for N_{cp} number of control points.

$$f_i(x) = C_3 \times t^3 + C_2 \times t^2 + C_1 \times t + C_0 \text{ where}$$

$$M_i = (x_{i+1} - x_i) \times m_i$$

$$M_{i+1} = (x_{i+1} - x_i) \times m_{i+1}$$

$$C_3 = 2y_i + M_i - 2y_{i+1} + M_{i+1}$$

$$C_2 = -3y_i + 3y_{i+1} - 2M_i - M_{i+1}$$

$$C_1 = M_i$$

$$C_0 = y_i$$

$$t = (x - x_i) / (x_{i+1} - x_i)$$

and gain function $G(x)$ which can be expressed as follows:

$$G(x) = \begin{cases} y_0 & \text{if } x < x_0 \\ y_i & \text{if } x = x_i \\ f_i(x) & \text{if } x_i < x < x_{i+1} \\ y_{N_{cp}-1} + \log_2 \left(\frac{x_{N_{cp}-1}}{x} \right) & \text{if } x > x_{N_{cp}-1} \end{cases}$$

Output Evaluator

Let H be an ordered list consisting of the union of the Baseline HDR Headroom and Alternate HDR Headroom. The Output Evaluator interpolates between Color Gain Functions as follows:

1. When target headroom value matches any of the HDR Headroom values, the Color Gain Function is applied directly to the data using the gain value as:

$$Gain(x) = 2^{G(x)}$$

And the resulting output value is:

$$Output\ value[component] = Gain([component]) * component$$

2. When the target headroom value falls between two HDR Headroom values, the gain is calculated by interpolating between the adjacent Color Gain Functions:

$$H_i < H_{target} < H_{i+1}$$

$$W_i = \left(\frac{H_{target} - H_{i+1}}{H_i - H_{i+1}} \right)$$

$$W_{i+1} = \left(\frac{H_{target} - H_i}{H_{i+1} - H_i} \right)$$

$$G(x) = W_i * G_i(x) + W_{i+1} * G_{i+1}(x)$$

$$Gain(x) = 2^{G(x)}$$

And the resulting output value is:

$$\begin{bmatrix} R_{out} \\ G_{out} \\ B_{out} \end{bmatrix} = Gain \left(\begin{bmatrix} R_{mix} \\ G_{mix} \\ B_{mix} \end{bmatrix} \right) * \begin{bmatrix} R_{inp} \\ G_{inp} \\ B_{inp} \end{bmatrix}$$

More details on the output evaluator are described in Clause 6.2.4 and 6.2.5 of specification SMPTE ST 2094-50:2026.

Notes:

1. for the Baseline HDR Headroom, $G(x)=0$ and corresponds to Zero Color Gain Function as described in Clause 6.3.3 of specification SMPTE ST 2094-50:2026.
2. The overall length of a headroomAdaptiveGainCurveTag shall be a multiple of four bytes, with null pad bytes added as needed, as defined in 7.1.2.
3. Specification SMPTE ST 2094-50:2026 does not require to be a multiple of 4 bytes. Care should be taken when transferring SMPTE ST 2094-50:2026 metadata to and from the headroomAdaptiveGainCurveType tag.

For the purpose of interoperability with video standards, the original specification of the Adaptive Gain Curve Tag was amended to match the binary form of the metadata described in specification SMPTE ST 2094-50:2026.

This specification defines only the layout and encoding of the headroomAdaptiveGainCurveTag, explaining how the SMPTE metadata mentioned above is added to an ICC profile, along with general definitions and concepts of using it for processing HDR data. The original SMPTE document shall be referred to for all the details.

Please visit <http://xxx.yyy.smpte/st2094-50> to access the original document (to be replaced with a final URL once the specification becomes public).

Annex 2 Backward compatibility (informative)

This annex provides guidance on creating a lutAToBType tag approximating the Headroom Adaptive Gain Curve.

2.1 Approximating Headroom Adaptive Gain Curve by lutAToBType for HDR to SDR tone mapping

A lutAToBType tag can be created to approximate the application of Headroom Adaptive Gain Curve for tone mapping an HDR image to SDR for backward compatibility with systems that don't support the concept of headroom. In this case, it is recommended that the A curves of the lutAToBType are used to linearize the input data, and the 3D CLUT is calculated by applying the Headroom Adaptive Gain Curve to a uniformly distributed 3D grid of RGB components. The CLUT is followed by a matrix converting RGB primaries to CIEXYZ.

2.2 Approximating Headroom Adaptive Gain Curve by lutAToBType or lutBToAType for SDR to HDR tone mapping

The Headroom Adaptive Gain Curve can be used to convert SDR to HDR. Accordingly, a lutAToBType or lutBToAType tag can be created for such a conversion. More importantly, a lutBToAType can be created to complement the lutAToBType tag based on Headroom Adaptive Gain Curve in a Display HDR profile. This can be accomplished either by applying the inverted Headroom Adaptive Gain Curve to a uniformly distributed 3D grid of RGB values, in a manner similar to that used for generating the lutAToBType, or by inverting the lutAToBType generated as described in Section 2.1 to produce the corresponding lutBToAType.

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