

MovieLabs Best Practices for Mapping BT.709 Content to HDR10 for Consumer Distribution v1.0

Introduction

Scripted studio content is typically color graded under the control of the content creator for each different, intended display system – whether it is cinema using the SMPTE digital cinema specifications, SDR consumer displays using Recommendation ITU-R BT.709, or HDR consumer displays using Recommendation ITU-R BT.2100. This process results in a content master that is approved by the content creator for a specific display system.

For the best consumer experience of the creative intent, content providers recommend that content be distributed and viewed using the display system for which it was created. In some cases however, operational constraints of consumer distribution systems or consumer devices may require studio content created for BT.709 to be displayed on a consumer HDR display using the HDR10 system, which includes the PQ EOTF (defined in SMPTE ST 2084 and ITU-R BT.2100) and static metadata (mastering display metadata defined in SMPTE ST 2086, along with MaxCLL and MaxFALL defined in CTA 861-G).

This document outlines MovieLabs' recommendations for how this mapping be performed for consumer display should it be necessary.

Use Cases

The following use cases may cause BT.709 SDR content to be mapped into an HDR10 format for consumer distribution or display.

1. A content distributor has an operational need to transmit SDR content using an HDR10 or BT.2100 PQ distribution format, e.g., a HDR broadcast channel.

If the content provider approves, the automated mapping described in this document should be used.

2. A device or system takes in a mixture of SDR and HDR content and automatically maps it to an HDR format because the user has chosen a device mode that maintains a consistent output format to the TV.

This needs to be done algorithmically and should use the method described in this document.

Considerations

These best practices are motivated by two goals. 1) Preserve the creative intent of the SDR version, as best possible given the operational constraints described above. 2) Provide a good and consistent experience to consumers viewing a mixture of SDR and HDR content.

Mapping of SDR Reference White Level

Based on studio viewing of consumer displays comparing SDR content in the display's SDR cinema mode and SDR content mapped to PQ, a 200 cd/m² reference white level yields the best overall results. ITU has also reported similar white point recommendations: report ITU-R BT.2408-0 recommends a nominal, common HDR Reference White level of 203 cd/m² for both PQ and HLG content (Section 2.2, Table 1); ITU-R BT.2390-3 in Section 10.1.2.3 provides a conversion of SDR to HLG using a reference white level of 203 cd/m².

Best Practices

Mapping from SDR (BT.709) to HDR (BT.2100 PQ)

The conversion consists of the following sequence of transformations.

1. Mapping the SDR content (signal E'_{SDR}) out to linear display light (F_{D_SDR}) using the BT.1886 EOTF (gamma 2.4) assuming the screen luminance (L_W) reference setting is 100 cd/m², and screen luminance black (L_B) is 0 cd/m².

$$F_{D_SDR709} = \text{BT.1886_EOTF}(E'_{SDR709})$$

2. Converting the colorimetry from BT.709 to BT.2020 using the color conversion matrix as specified in the "M2" transformation in BT.2087.

$$F_{D_SDR2020} = \text{BT.709toBT.2020}(F_{D_SDR709})$$

3. Scaling the peak white to 200 cd/m².

$$F_{D_HDR} = \text{SDRtoHDRscaling}(F_{D_SDR2020})$$

4. Mapping the HDR linear to PQ using the PQ inverse-EOTF.

$$E'_{PQ} = \text{BT.2100_PQ_EOTF}^{-1}(F_{D_HDR})$$

The BT.1886_EOTF and BT.2100_PQ_EOTF⁻¹ are applied to the individual red, green and blue components.

The SDRtoHDRscaling function is a simple multiplication of each component by a factor of 2.0.

Generation of Static Metadata

The output signal should include SMPTE ST 2086 Mastering Display Metadata with the following payload.

- Color primaries and white point should be set to BT.709 (the format of the incoming video).
- Mastering display maximum luminance should be set to 200 cd/m².
- Mastering display minimum luminance should be set to 0, indicating unknown.

The output may include MaxCLL and MaxFALL metadata. If it does, the payload should be as follows:

MaxCLL

- BT.709 versions of scripted studio content consistently have a significant number of pixels at peak white, and these peak white values will convert to 200 cd/m² using the recommend conversion, thus the MaxCLL value should be set to 200 cd/m². Alternatively, analysis of the converted content can be performed to determine the MaxCLL value.

MaxFALL

- Should be set to 0 cd/m², indicating unknown. Alternatively, analysis of the converted content can be performed to determine the MaxFALL value.

User Choice of Display Modes

In addition to the automatic mapping process outlined above, consumers should always have the following options:

- Settings choice that will cause the display to switch into a mode with the *native dynamic range* of the content, if the display supports such a mode.
- Settings choice that will cause the display to switch into a mode with the *native frame rate* of the content, if the display supports such a mode.

References

CTA, CTA 861-G. "A DTV Profile for Uncompressed High Speed Digital Interfaces," (11/2016).

ITU-R, Recommendation ITU-R BT.709-6, "Parameter values for the HDTV standards for production and international programme exchange," (06/2015).

ITU-R, Recommendation ITU-R BT.1886, "Reference electro-optical transfer function for flat panel displays used in HDTV studio production," (03/2011).

ITU-R, Recommendation ITU-R BT.2035, "A reference viewing environment for evaluation of HDTV program material or completed programmes," (07/2013).

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ITU-R, Recommendation ITU-R BT.2087-0, "Colour conversion from Recommendation ITU-R BT.709 to Recommendation ITU-R BT.2020," (10/2015).

ITU-R, Recommendation ITU-R BT.2100-0, "Image parameter values for high dynamic range television for use in production and international programme exchange," (07/2016).

ITU-R, Report BT.2390-3, "High dynamic range television for production and international programme exchange," (10/2017).

ITU-R, Report BT.2408-0, "Operational practices in HDR television production," (10/2017).

SMPTE, ST 2084:2014, "High Dynamic Range Electro-Optical Transfer Function of Mastering Reference Displays"

SMPTE, ST 2086:2014, "Mastering Display Color Volume Metadata Supporting High Luminance and Wide Color Gamut Images"