



NBCUniversal
Single-Master Broadcast
HDR-SDR Production and Distribution
Recommendations

NBCU-Rec-UHD-HDR-1.23

10/24/25

| | |
|---|-----------|
| 1. Introduction | 4 |
| 2. Dual-Focused Single-Master HDR Workflow Guide | 5 |
| 2.1.Signal Flow from Production to Distribution | 5 |
| 2.2.Initial Reference Display Initial Settings before calibration | 9 |
| 2.3.Setting Viewing Conditions for HDR and SDR monitoring in close proximity within a single-master production environment | 9 |
| 2.4.HDR-to-SDR Interlacing Optimizations | 10 |
| 4. NBCU HDR/SDR Conversion LUTs | 10 |
| 4.1.DaVinci Resolve (using NBCU LUTs) | 11 |
| 4.2.Adobe Premiere (using NBCU LUTs) | 12 |
| 4.3.Avid Media Composer (with NBCU LUTs) | 15 |
| 4. HDR Cross-Conversion LUTs from NBCU | 16 |
| 5. Still Image Formats for native HDR graphics (BRAND NEW) | 16 |
| 5.1.PNG 3rd Edition (CICP Chunk) | 16 |
| 5.2.TIFF (ICC CICP Tag) | 18 |
| 5.3.Full Range vs Narrow Range images | 18 |
| ANNEX 1: The Strategy Around NBCU LUT Conversions | 20 |
| ANNEX 2: 3D Cube Look-Up-Tables (3D-LUT) | 21 |
| 3D LUT Interpolation Modes | 22 |
| ANNEX 3: Shading Detail | 24 |
| ANNEX 4: Production and Distribution Video Formats | 26 |
| 5.1.Why Use HLG For Production? | 26 |
| 5.2.Why Use PQ For Distribution? | 26 |
| ANNEX 5: WAVEFORM MONITOR REFERENCE SCREENSHOTS | 27 |
| ANNEX 6: Objective Color Metric Measurement | 37 |
| ANNEX 7: Signal Level Relationships During Conversion | 40 |
| a. SDR->HLG->SDR ROUNDTRIP MAPPINGS: | 42 |
| b. PQ MAPPINGS (SDR-PQ-SDR): | 43 |
| c. HLG -> PQ LEVEL MAPPINGS: | 44 |
| d. NBCU LUT CONVERSION ANCHOR POINTS: | 45 |
| ANNEX 8: ITU-R BT.2408 Workflow Drawing | 46 |
| ANNEX 9: ITU-R BT.2408 Conversion Detail | 46 |
| Annex 10: NABA-NBCU-MovieLabs TV Luminance Survey Summary | 47 |

| | |
|---|-----------|
| Reference | 48 |
| Acronyms | 49 |
| Reference Files, Tools and Test Patterns | 50 |
| Document History | 51 |

Single-Master HDR-SDR Workflow Recommendations

1. Introduction

For movies and early broadcast trials, creating HDR/SDR content versions has required separate grading/shading and mastering processes. As dual live production workflows are impractical, a “Single-Master” approach that can deliver both emerging UHD/HDR and legacy HD/SDR formats simultaneously has been devised. The process utilizes available technology to maximize the dynamic range and color volume in HDR, while improving the quality of the the core legacy HD/SDR broadcasts.

In collaboration with Cromorama, and building on ITU working group discussions involving Dolby, BBC and Technicolor, NBCU has developed “Single-Master” production and distribution techniques. These techniques and supporting conversions have been developed using objective color science standardized in [Recommendation ITU-R BT.2124](#) as well as with traditional real-world testing.

The LUTs (Look-Up-Tables) included in this repository are free for public use. We ask that manufacturers that use them include "NBCU" in the file/conversion name, do not alter the header of each LUT, and finally acknowledge in their license to customers that the LUTs were “developed by NBCUniversal Media, LLC”. They are distributed publicly and freely without warranty on an “as is” basis in an effort to encourage UHD Single-Master HDR-SDR production with consistent media exchange”.

The NBCU “Single-Master” HDR-to-SDR down-mappers goal is to preserve the look of HDR while compressing HDR highlights above reference white in the final derived-SDR images for display on todays typically brighter SDR TV's ([see luminance study in Annex 10](#)). Using this process, an HDR image may be placed next to a down-mapped SDR image and they will match (minus compressed highlights that are only possible with the native HDR content). In this conversion, a knee slope begins slightly below HDR reference white so that additional highlights can be preserved in the remaining range of SDR all the way up to 109% of the signal level. Greater detail regarding the signal flow is available later in this document.

The NBCU “Single-Master” SDR-to-HDR direct up-mapper follows the [MovieLabs recommendation](#) to apply a 2.03x linear scaling during direct upmapping such that the SDR “Look” mimics a BT.1886 display set at a luminance level of 203 cd/m². BT.1886 is the reference EOTF for SDR displays. Essentially this means that the SDR image direct up-mapping provides a familiar viewing experience of today's typically higher luminance consumer SDR TV's when preserved within the HDR image (container).

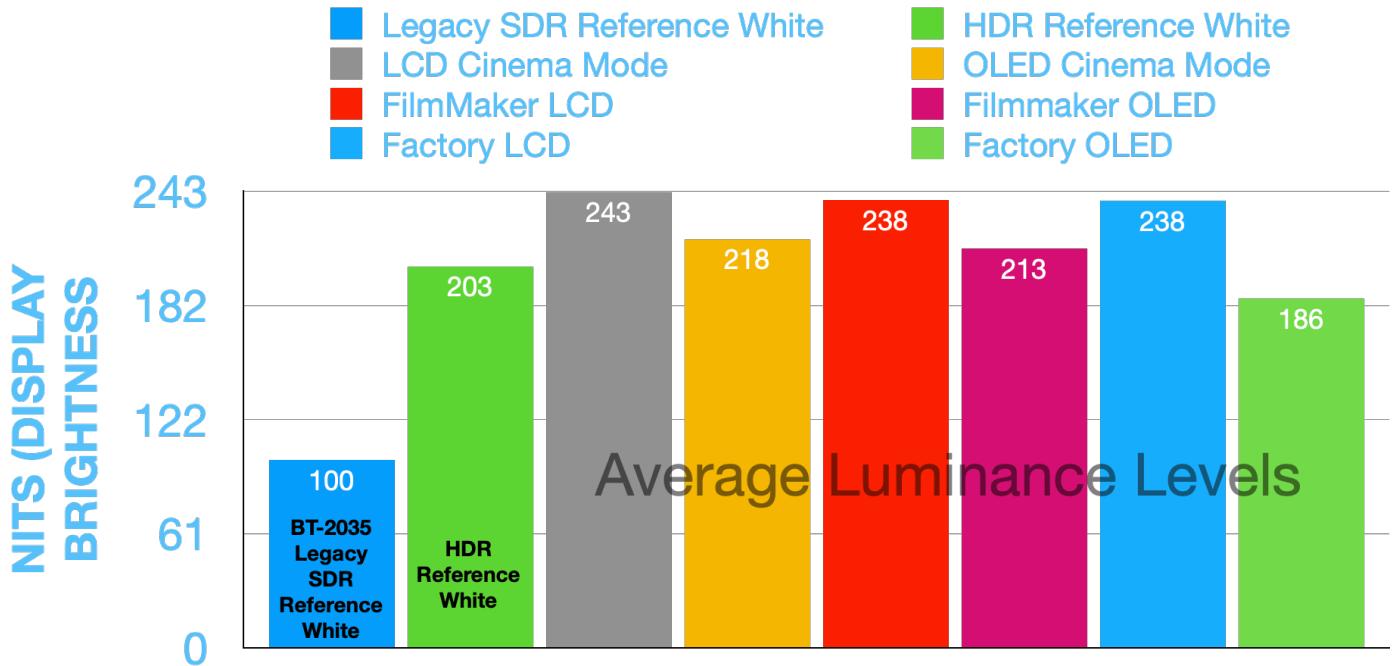
The monitoring techniques used in this recommendation are now documented in ITU-R BT.2166 “Method B” which defines the conditions for side-by-side monitoring of HDR and SDR images.

Our down-mapper is complementary to the [MovieLabs](#) direct up-mapper. The down-mapper reverses the scaling of the up-mapper between black and reference white by using a (approximately) .5x linear display light scaling during HDR-to-SDR conversion. Finally, the BT.1886 display set at typical consumer luminance levels applies a linear scaling of approximately 2 times so that an excellent roundtrip from SDR-to-HDR-back-to-SDR is possible.

This workflow document provides a potential best practice for broadcast production and distribution processes including conversion. We are sharing our experiences to continue a dialog with our colleagues so that consistent creation, delivery and media exchange of HDR and SDR content is possible.

The following graph is a simple summarized plot from the co-funded NABA/MovieLabs/NBCUniversal study which validates our assumptions regarding consumer TV viewing experiences. The study occurred at the DTG Zoo with volunteers from NBCU, BBC, Sky, Dolby and Cromorama. Specifically, it measured the SDR TV luminance of consumer TV's in several picture modes and also the “effective-gamma” (measuring tone stretching) which affects **average** luminance. The study verified that average consumer TV's are approximately double the luminance of yesterdays CRT-based TV's and todays traditional SDR reference displays. While peak luminance was fairly consistent (@ approximately 2x), different picture modes altered the gamma curve (and possibly other characteristics) which raises **average** luminance.
[See details in Annex 10:](#)

Single-Master HDR-SDR Workflow Recommendations



2. Dual-Focused Single-Master HDR Workflow Guide

2.1. Signal Flow from Production to Distribution

We believe that a dual-focused Single-Master live production workflow enables efficient productions with the highest possible quality while managing cost and taking advantage of additional operational efficiencies. Live HDR productions can be performed in Hybrid Log Gamma (HLG) BT.2100. For distribution, live production feeds can be converted to PQ in order to maintain optimal and consistent consumer TV display luminance levels.

Amidst an evolving multi-format landscape, it is crucial to integrate accurate and consistent format conversions to ensure interoperability between HLG, PQ and SDR sources and platforms. This is especially important with the new video formats capabilities in color, dynamic range, and the subsequent conversion between them.

A Dual-Focused Single-Master production workflow includes a combination of native HLG and SDR sources. In this model, SDR content is converted to HLG prior to inclusion into the HDR (Master) production environment. The final HLG production is then converted to PQ for transmission. All conversions are performed mathematically or through LUTs (Look Up Tables) as described in Annex 1.

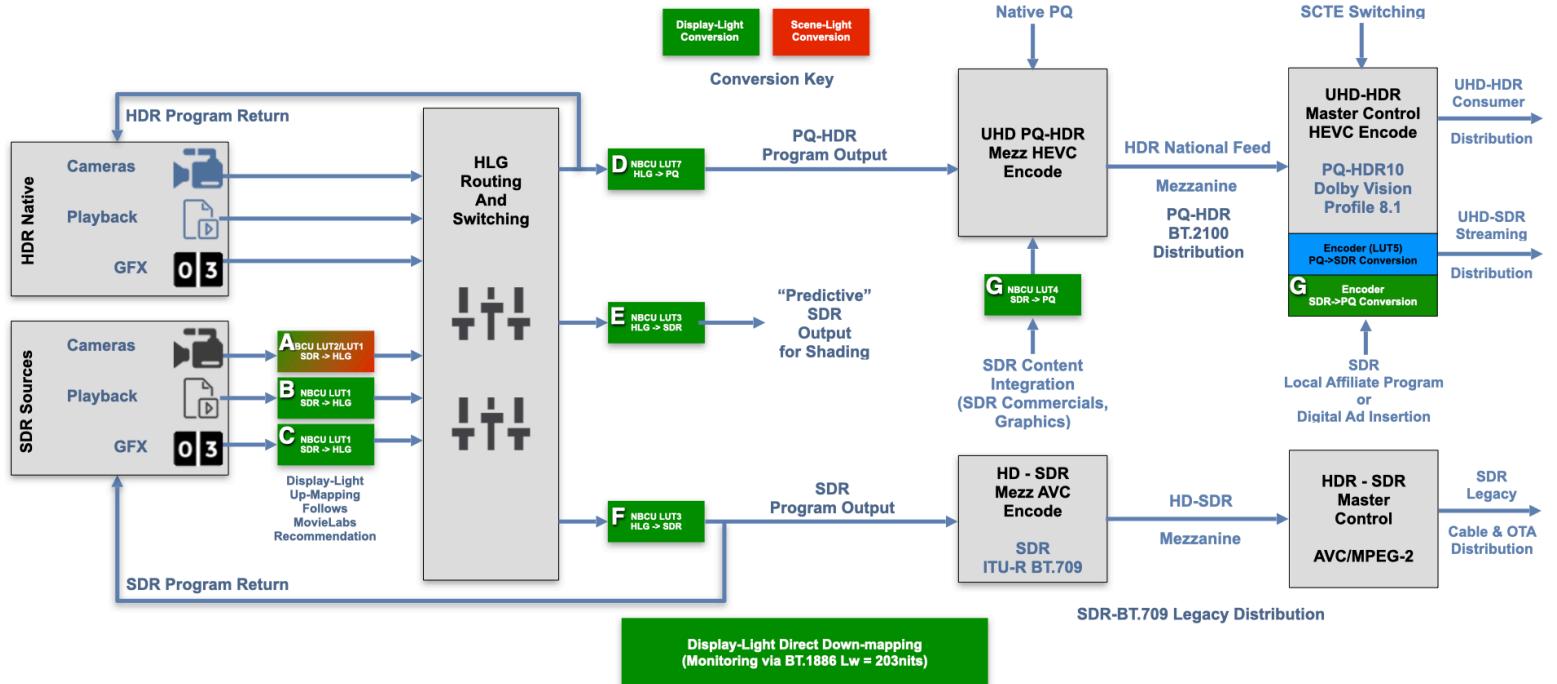
Figure 1, illustrates the end-to-end signal flow for multi-format sources and conversion points (conversions are identified by letters A-F)

Figure 1 - Single-Master HDR/SDR Live Production – HLG Production to PQ Transmission (Simplified)

PRODUCTION CONVERSIONS

- **All Native HLG sources:** Available on the source router and available to the video switcher without any conversion.
- **SDR Cameras Source - “A”:** **NBCU LUT1 or 2** perform an SDR to HLG conversion using either **“scene light”** or **“display light”**. Scene-light conversions attempt to match the native look of HLG which is slightly less saturated. Display-light conversions match the native look of SDR into an HLG “container”.

Single-Master HDR-SDR Workflow Recommendations



- **SDR Playback Source- “B”:** NBCU LUT 1 performs an SDR to HLG conversion using “*display light*” to preserve the original artistic intent (the SDR look).
- **SDR Graphics Source - “C”:** NBCU LUT 1 performs an SDR to HLG conversion using “*display light*” to preserve the original artistic intent (the SDR look).
- **HLG-to-SDR Predictive LUT - “E”:** NBCU LUT 3 converts from HLG to SDR using display light and acts as a “predictive LUT” so that a shader can preview the “look” of SDR transmission.

DISTRIBUTION CONVERSIONS

- **HLG-to-PQ Output - “D”:** NBCU LUT7 converts transparently between HLG and PQ using “*display light*” to preserve the original artistic intent (the HLG look).
- **HLG-to-SDR Production Output - “F”:** NBCU LUT 3 converts HLG to SDR using “*display light*” and a sophisticated 2-stage highlight compression knee to reduce the dynamic range and color gamut while preserving much of the artistic intent.
- **SDR-to-PQ Distribution Conversion - “G”:** NBCU LUT 4 performs an SDR to PQ conversion using “*display light*” to preserve the original artistic intent (the SDR look).

ANNEX 3 & 4 PROVIDE FURTHER DETAILS ON THE CONVERSION PROCESSES Basic Shading and Video Monitoring Practices

In the Single-Master production workflow described in Figure 1, camera shading is performed in HLG BT.2100 using HLG reference displays¹. We provide a “predictive” conversion for the video operator so that SDR created for transmission can be monitored. The NBCU HDR to SDR LUT is designed to maintain the creative intent inside of the boundaries of SDR when compressing the HDR in a consistent manner.

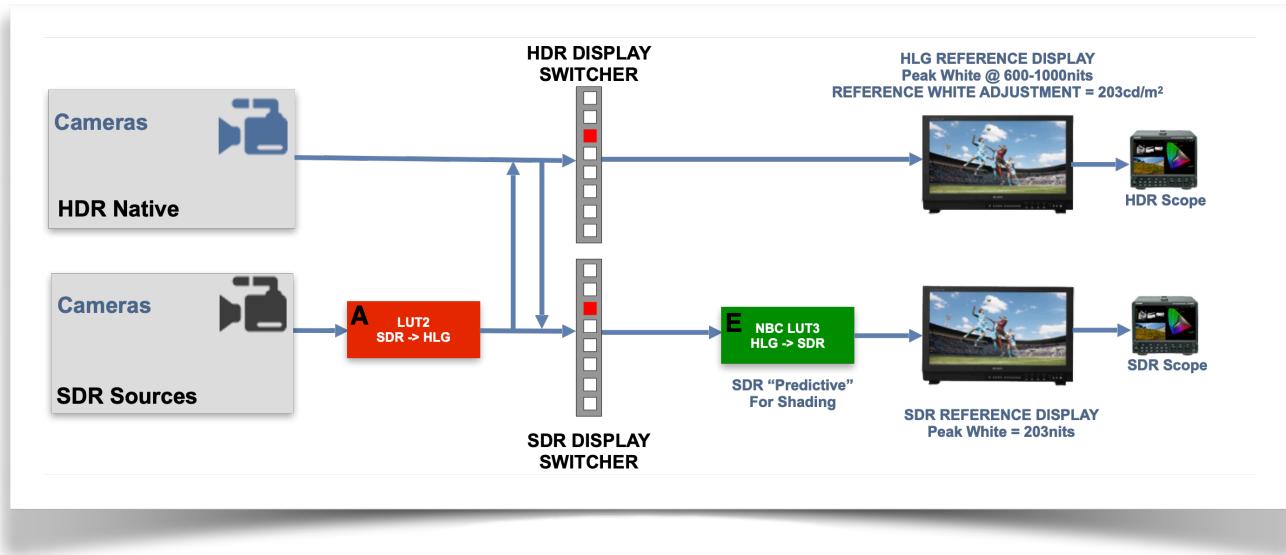
¹It is possible to shade in SDR thru the predictive NBCU LUT 3, but it is preferred to use the HDR display as the primary shading display.

A. Shading Cameras: Setting up HDR and SDR Displays for Monitoring Side-by-Side

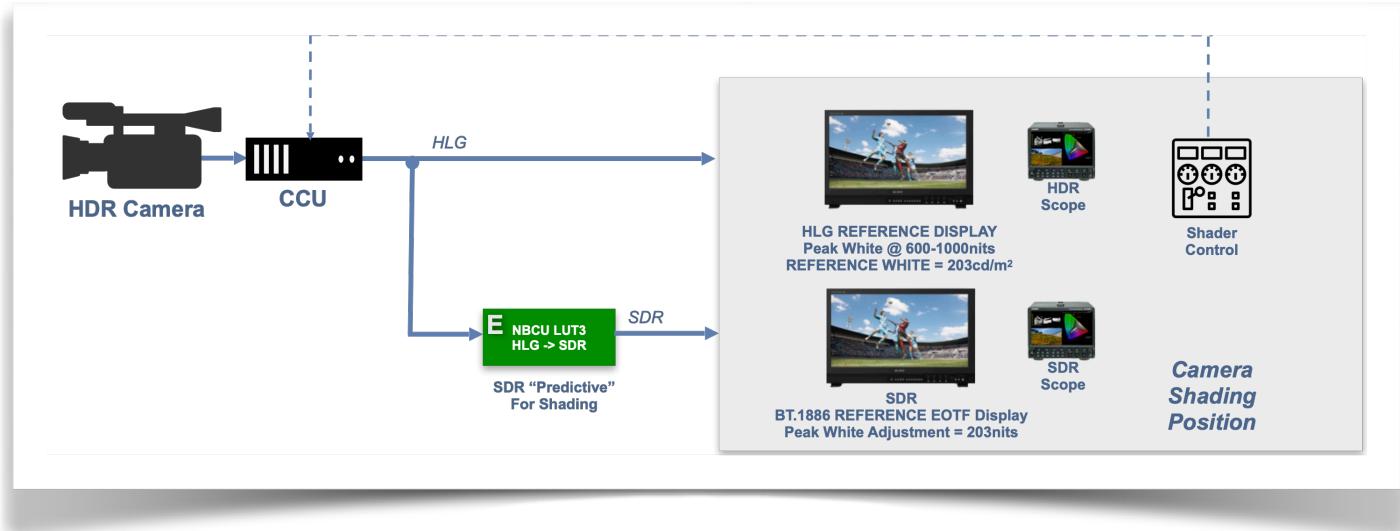
Single-Master HDR-SDR Workflow Recommendations

- When shading HDR and SDR, we prefer to have an HDR and SDR monitor side-by-side (in close proximity) using the techniques defined in Method B of ITU-R BT.2166.
- Native HDR cameras are shaded on an HLG reference display where “Reference White” is 203 cd/m² as defined in ITU-R Report BT.2408. No adjustments are necessary on 1,000cd/m² HLG displays. Because of the relative nature of HLG, displays below 1,000cd/m² are adjusted using the contrast control so reference white matches the SDR shading display.
- The HLG camera signal is passed thru NBCU LUT3 (what we call the “Predictive LUT”) to enable shaders to preview the camera’s appearance as it will be seen thru legacy SDR transmission. Generally this is fed by the router and can also be switched to the program output.
- SDR camera signals are converted to HLG using **NBCU LUT 1 or 2** and shaded on an HLG reference display with **NBCU LUT3** providing a “predictive” preview of SDR. Set SDR displays peak-white to 203 cd/m².

PLEASE REFER TO ANNEX 3-7 FOR DETAIL ON SHADING PRACTICES AND REFERENCE LEVELS

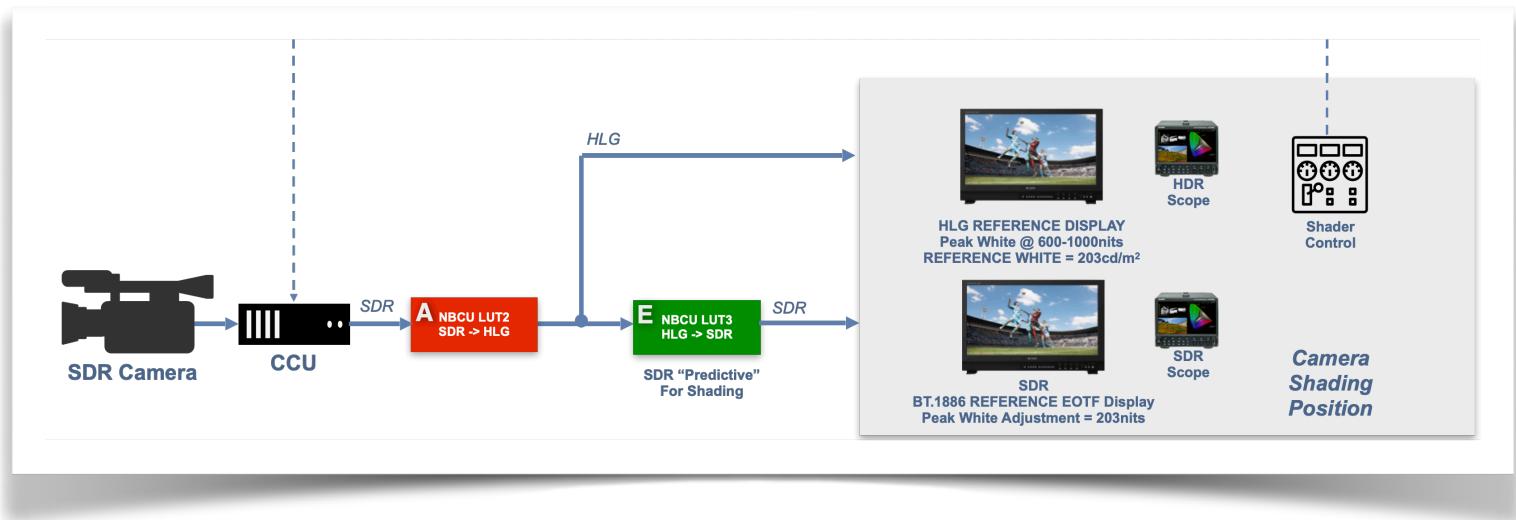


HDR Camera Shading in a Single-Master Workflow



Single-Master HDR-SDR Workflow Recommendations

SDR Camera Shading in a Single-Master Workflow



Single-Master HDR-SDR Workflow Recommendations

2.2. Initial Reference Display Initial Settings before calibration

2.3. Setting Viewing Conditions for HDR and SDR monitoring in close proximity within a single-master production environment

There is now an international standard (ITU) for setting up HDR and SDR monitors in close proximity. It is based on the concept which the LUTs themselves operate under where we anchor the luminance levels of each display around diffuse or HDR Reference white. The new standard is ITU-R BT.2166. We operate under conditions described in "Approach B" where the HDR displays diffuse/reference white follows ITU-R BT.2408 recommendations and the SDR displays peak white is adjusted to the same level.

Parameters for the SDR display adjustment

| Adjustment parameter | Value |
|--|------------------------------------|
| Peak luminance of SDR display (L_w adjustment (Contrast) described in Rec. ITU-R BT.1886) | HDR reference white ⁽¹⁾ |

- ⁽¹⁾ The SDR display luminance should be adjusted to match the HDR reference white luminance level of the production, noting that Report ITU-R BT.2408 describes a nominal HDR reference white of 203 cd/m².

When setting up displays for a control room, the essential goal is to make sure all HDR and SDR use the same diffuse/reference white luminance levels. This prevents eye adaptation issues where the human visual system adjusts to specific luminance levels. Eye adaption issues prevent content creators from making more objective comparisons when focusing on adjacent HDR and SDR images that are in close proximity.

| SDR / HDR MONITOR WHITE SETTINGS: FIXED-LEVEL REFERENCE WHITE 2025 | | | | | | | | | |
|--|----------------|--------------------|-------------------------|---------------------|----------------|--------------------|-------------------------|---------------------|-------------------------|
| *** Modify Picture Adjustment Presets so contrast values follow the HDR or SDR input selection *** | | | | | | | | | |
| | SDR | | | | HDR | | | | |
| | CONTRAST VALUE | MAX CONTRAST VALUE | OUTPUT LUMINANCE (nits) | COLOR SPACE / GAMMA | CONTRAST VALUE | MAX CONTRAST VALUE | OUTPUT LUMINANCE (nits) | COLOR SPACE / GAMMA | |
| BVM-HX1710 | 812 | 200 | 203 | 709 / 2.4 | BVM-HX1710 | 200 | 1810 | 2000 | BT.2020 / BT.2100 (HLG) |
| | 812 | 1000 | 203 | 709 / 2.4 | | 400 | 1000 | 1000 | BT.2020 / BT.2100 (HLG) |
| PVM-X2400 | 812 | 1000 | 203 | 709 / 2.4 | PVM-X2400 | 400 | 1000 | 1000 | BT.2020 / BT.2100 (HLG) |
| PVM-X1800 | 812 | 1000 | 203 | 709 / 2.4 | PVM-X1800 | 400 | 1000 | 1000 | BT.2020 / BT.2100 (HLG) |
| BVM-X300 | 812 | 1000 | 203 | 709 / 2.4 | BVM-X300 | 400 | 1000 | 1000 | BT.2020 / BT.2100 (HLG) |
| BVM-E171 | ~1845-1885 | 2030 | 203 | 709 / 2.4 | BVM-E171 | ~1845-1885 | ? | 1000 | BT.2020 / HLG 1.2 |
| PVM-A240 | 100 | tbd | 175 | 709 / 2.4 | PVM-A240 | 80 | 100 | 260 | BT.2020 / BT.2100 (HLG) |
| PVM-A170 | 100 | 250 | tbd | 709 / 2.4 | PVM-A170 | 85 | tbd | tbd | BT.2020 / BT.2100 (HLG) |
| LMD-A240 | 91 | 100 | tbd | 709 / 2.4 | LMD-A240 | 80 | 100 | tbd | BT.2020 / BT.2100 (HLG) |

Single-Master HDR-SDR Workflow Recommendations

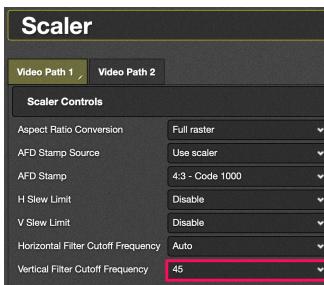
If HDR/SDR images use a unified diffuse/reference white luminance level, issues with eye adaptation can be reduced.

For SDR reference displays, the contrast control is adjusted to double the typical value of a typical SDR reference display. The contrast control adjusts peak luminance using a linear scaling of the entire luminance range. Consumer displays need very little adjustments because they default to a peak white brightness closer to 203 cd/m². Consumer displays in the Cinema/Picture modes use a gain factor that is equal to or very close to a linear scaling as described in the SDR reference EOTF (ITU-R BT.1886). BT.1886's peak white is adjustable using the contrast control which applies a linear scaling factor. ITU-R BT.2129 describes the use of this adjustment for program master monitoring with a range between 100-250 cd/m². The proper picture mode must be selected on both HLG or SDR (Filmmaker or Cinema mode). For SDR consumer displays, it is important to verify that gamma is set to BT.1886 (sometimes it will default to gamma 2.2). Gamma 2.2 was used in earlier, darker displays that could not achieve a higher PEAK brightness so they raised the average brightness by stretching shadows and midtones. It is the opposite of what you should do with todays brighter displays because it will expose noise and blanch flesh tones.

2.4. HDR-to-SDR Interlacing Optimizations

When converting from 2160P or 1080P (progressive) to 1080i (interlaced) formats of video, a vertical filter must be applied in order to avoid hi-frequency elements being introduced which causes additional blocking artifacts in MPEG2 encoding (typically in ATSC1 Transmission).

- One examples would include the settings for an Evertz MIO:



- Grass Valley XiP 3901 cards should be left in their default vertical filtering selection.
- Imagine SNP's is still being tested but it is assumed the values will be somewhere between a quarter-band and half-band filter. A quarter band filter has a value of -20.

4. NBCU HDR/SDR Conversion LUTs

NBCU has a commitment to industry collaboration and would like to encourage consistent media exchange, therefore we are willing to provide the NBCU LUTs freely. The NBCU LUTs are provided on an "as is" basis with no warranties.

Please contact: chris.seeger@nbcuni.com for a link to the NBCU Single-Master LUTs package and documentation.

Both **NBCU LUT3** and **NBCU LUT5** use a unique "color primary tracking technique" and a sophisticated 2-stage knee for down-mapping of color and light in order to achieve an optimized preservation of the original artistic intent during conversion that reduces the dynamic range and color from HDR to SDR. Below are the LUTS for hardware devices followed by LUTS which are specific to software-based editing platforms.

| A. HLG-BT.2100 (to/from SDR-BT.709) | | |
|-------------------------------------|----------------------------|--|
| LUT | NAME | Description |
| 1 | 1-NBCU_SDR2HLG_DL_v1(cube) | Up-maps legacy SDR signals into a native HLG production using display-light conversion. |
| 2 | 2-NBCU_SDR2HLG_SI_v1(cube) | Tonemaps and matches SDR cameras with the HLG "Look" for a native HLG production using scene-light conversion. |
| 3 | 3-NBCU_HLG2SDR_DL_v1(cube) | Down-maps native HLG-BT.2100 signals to SDR as a predictive LUT or for legacy SDR-BT.709 transmission. |

| B. PQ-BT.2100 (to/from SDR-BT.709) | | |
|------------------------------------|---------------------------|--|
| LUT | NAME | Description |
| 4 | 4-NBCU_SDR2PQ_DL_v1(cube) | Up-maps legacy SDR signals into a native PQ production or transmission. |
| 5 | 5-NBCU_PQ2SDR_DL_v1(cube) | Down-maps native PQ-BT.2100 signals to SDR-BT.709 as a predictive LUT or for legacy SDR-BT.709 transmission. |

Single-Master HDR-SDR Workflow Recommendations

An alternate approach for HDR<->SDR conversion during a “Single-Master” production is used by the BBC which lifts shadows and midtones in an attempt to optimize down-mapped SDR for viewing on 100 cd/m² technical display. A conversion LUT between both approaches is available. The BBC approach is also known as the “gamma-adjusted” method. It is not optimized for todays higher luminance SDR TV’s and also tends to lower the exposure of the HDR images. More information on this approach is documented in ITU-R BT.2408.

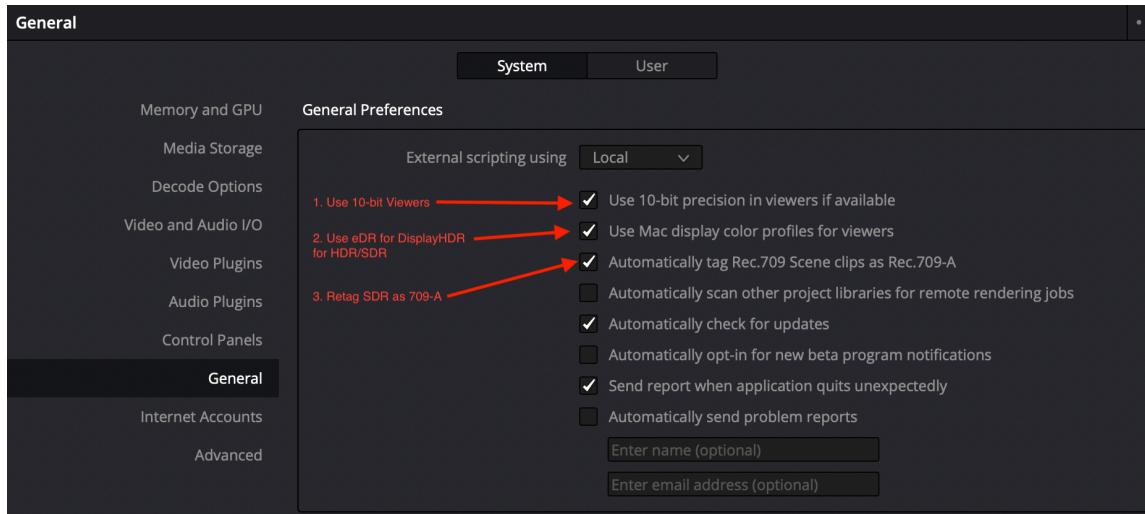
4.1. DaVinci Resolve (using NBCU LUTs)

There are special application-specific cube LUTs for **DaVinci Resolve 17** that use a special video tag for use with video range projects. They are contained in a DaVinci Resolve-labeled folder and tagged within the filename with “VRT”.

In order to properly view HDR and SDR content, the display settings should be changed:

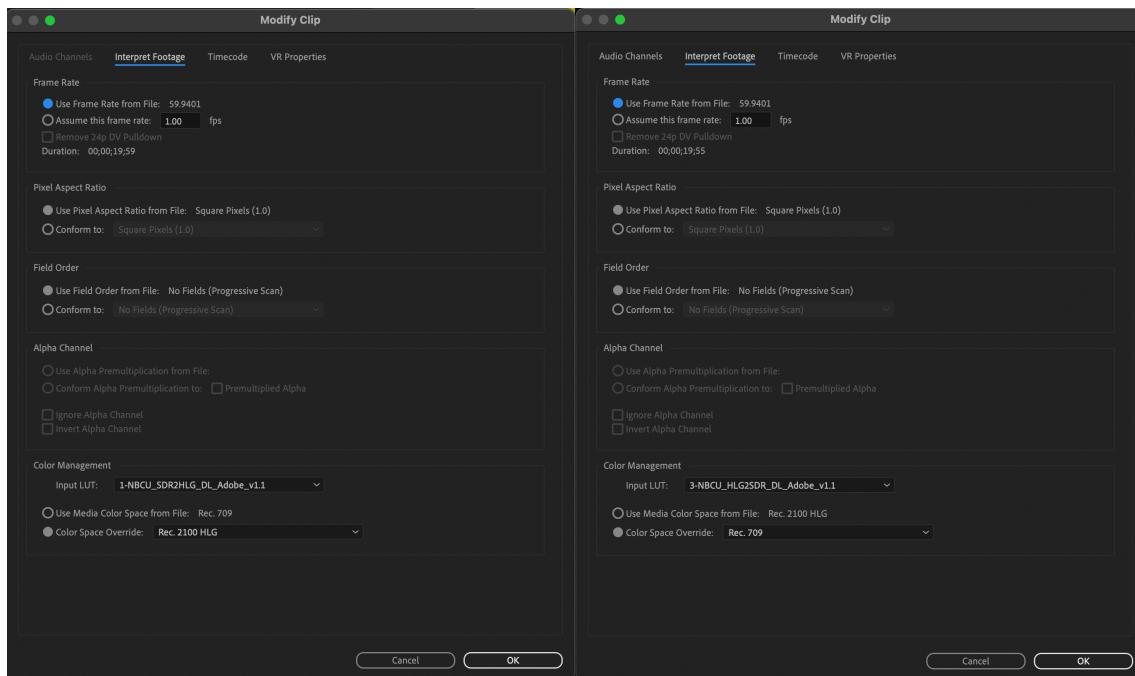
- To support 10-bit viewers (required to prevent banding, especially in HDR)
- To retag SDR content with 709-A so that exports will have the right CICP value read by most applications as SDR (BT.709)
- To support eDR in MacOS which uses DisplayHDR on desktop computer displays to properly color manage SDR and HDR content for display.

Single-Master HDR-SDR Workflow Recommendations



4.2. Adobe Premiere (using NBCU LUTs)

Adobe Premiere Pro >2022 Complete HDR Workflow Guide: <https://adobe.ly/hdr>

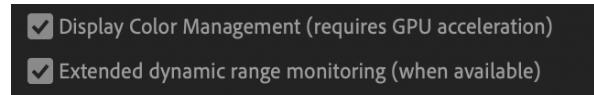


Adobe Premiere uses a slightly different cube LUT format. They are contained in an Adobe-labeled folder. A maintenance release from June 2021 is required for Tetrahedral interpolation. To apply a LUT, click on the media file and navigate using the dropdown menu to "Modify/Interpret footage". Using the selection seen in the screen captures below, select a LUT and "Color Space Override". The LUTS are contained in an Adobe-labeled folder.

Single-Master HDR-SDR Workflow Recommendations

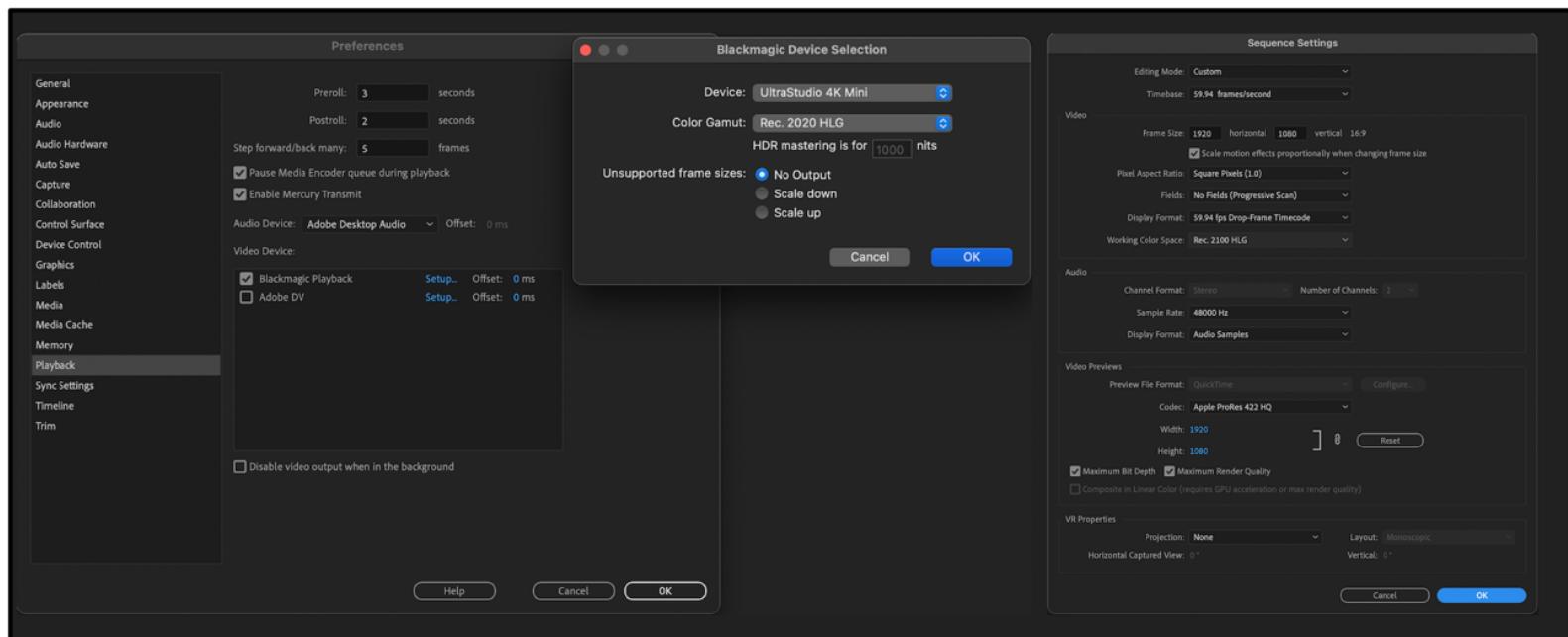
When the Desktop Computer Display supports VESA DisplayHDR or is an Apple XDR

- Open Preferences and click on “General”
- Click on Display Color Management and Extended Dynamic Range



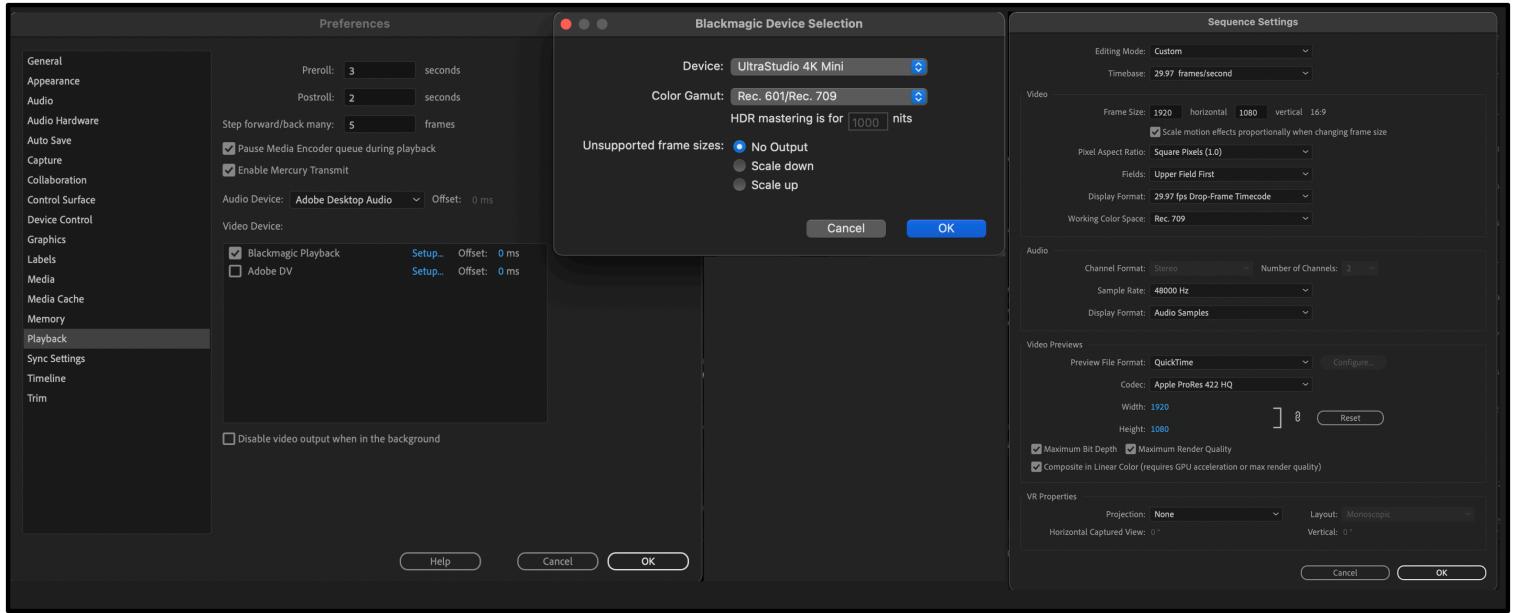
Below are Adobe Premiere the preferences for HLG Video IO and sequence Settings. Each setting will determine the baseband and file-based output video formats

Adobe Premiere Video IO Preferences / Sequence Settings for HLG-BT.2020



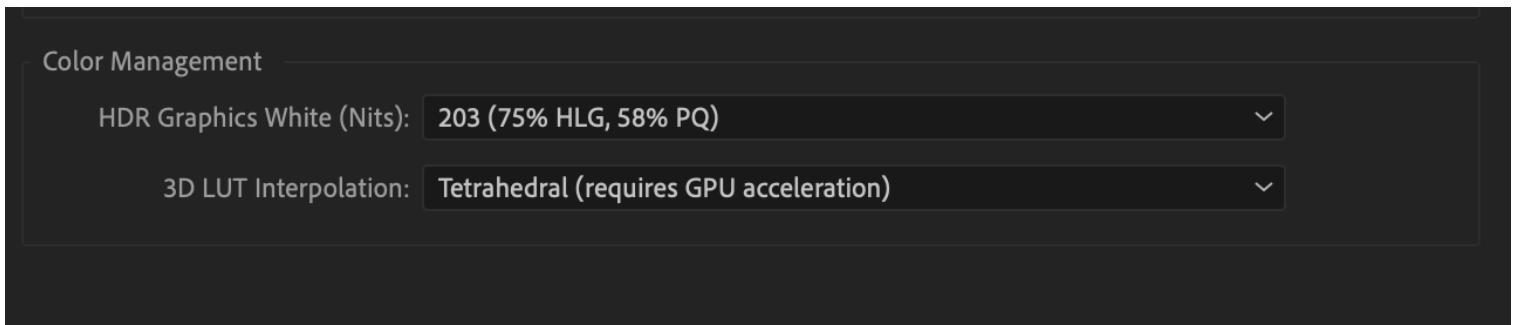
Single-Master HDR-SDR Workflow Recommendations

Adobe Premiere Video IO Preferences / Sequence Settings for SDR-BT.709



Adobe Premiere HDR workflows have some LUT conversion accuracy issues which we are still studying.

Adobe Premiere Project Settings: Reference White = 203nits; 3D LUT Interpolation = Tetrahedral

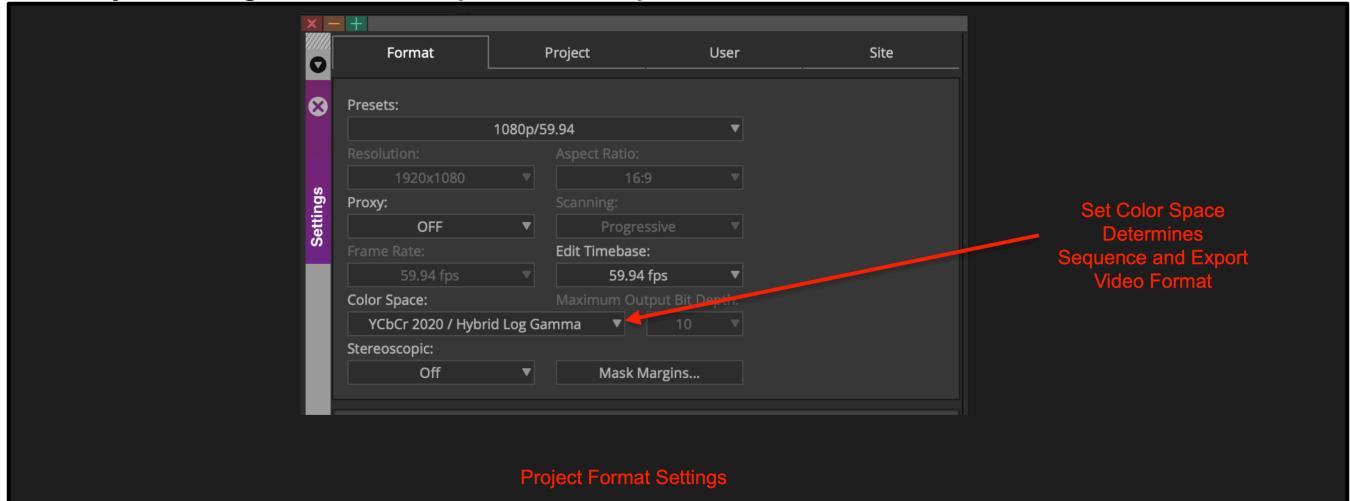


Single-Master HDR-SDR Workflow Recommendations

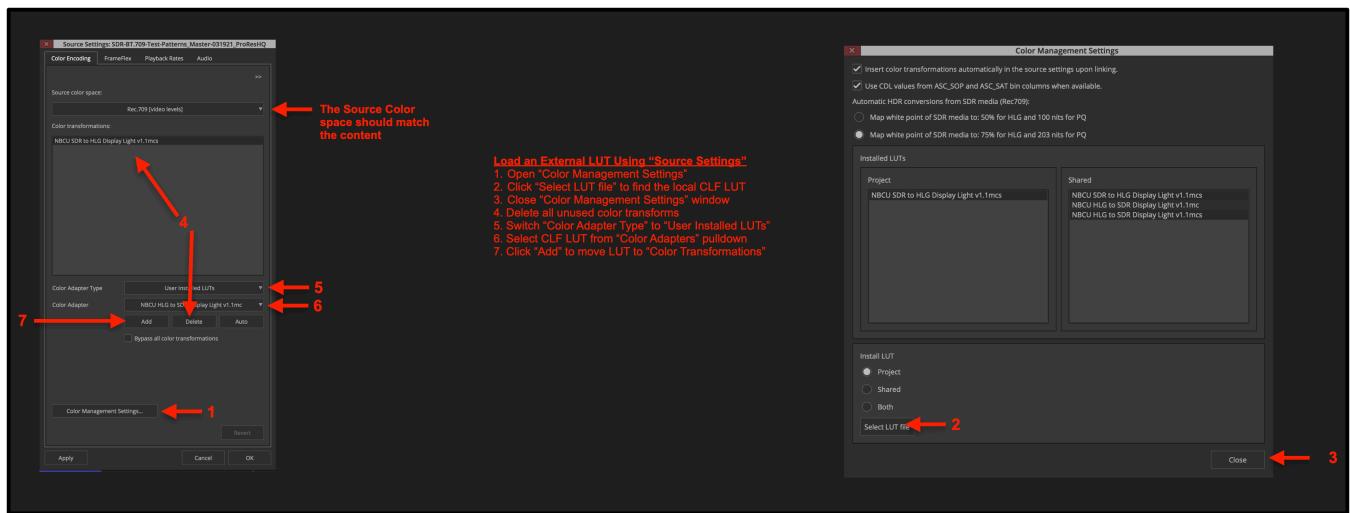
4.3. Avid Media Composer (with NBCU LUTs)

There are special **CLF LUTS** for **Avid Media Composer** because it does not support Type III LUTS natively. In order to support sub-blacks and super-whites we use unique **CLF LUTs**. Use the “Source-Settings” dialog to add a CLF LUT. The current Avid CLF LUTs work around current issues with the conversion pipeline by scaling and unscaling full-range video into a narrow-range “container”. In addition, a special matrix compensation is applied to compensate for the different scaling factors and conversion between YCbCr and RGB (the conversion occurs in a RGB color representation).

- Avid Project Settings determine Sequence and Export video format**



- Avid “Source Settings” determine source conversions using a CLF LUT**



Single-Master HDR-SDR Workflow Recommendations

4. HDR Cross-Conversion LUTs from NBCU

Below is a list of HLG-to-PQ cross conversion LUTs and a description of their purposes.

| A. HLG to PQ | | | |
|--------------|---------|-------------------------|--|
| Name | Version | NAME | Description |
| NBCU LUT 7 | 1 | 7-NBCU-HLG10002PQ(cube) | BT.2100 HLG signals are converted to BT.2100 PQ at the 1,000nits “bridge” condition, so that 100% HLG maps to 1,000nits PQ. This is a transparent conversion. This LUT is freely distributed. |

5. Still Image Formats for native HDR graphics (BRAND NEW)

In order to produce native HDR and SDR graphics it is important to be able to identify what format they contain so that the images can be displayed properly. Video wrappers and streaming codecs have had the ability to do so for a very long time using signaling values defined in [ITU-T H.273](#). This information is also valuable for archives for correct identification of the files image characteristics. Below is a table which defines the specific characteristics which are essential:

For the past several years, NBCUniversal has been working hard in standards groups to establish methods for signaling in still image formats and two methods have been released. PNG 3rd Edition has a CICP chunk and ICC profiles now have a CICP tag. All of this functionality is brand new and a lot of testing is still necessary to develop workflows with them.'

| CICP | Examples | Purpose |
|---------------------|-----------------|---|
| Color Primaries | BT.709, BT.2020 | Identify Color Space |
| Transfer Function | SDR, PQ, HLG | Identify light mapping formula |
| Matrix Coefficients | BT.709, BT.2020 | Identify equation for conversion from YC _B C _R <> RGB |
| Full Range Flag | 1 or 0 | 1 = Full Range(default) 0 = Limited/Narrow |

5.1. PNG 3rd Edition (CICP Chunk)

PNG 3rd Edition which is about to be released by W3C has the ability to signal video formats explicitly just like movie files.

MacOS has implemented PNG 3rd Edition with the exception(so far of the full-range-flag which is about to be released by W3C has the ability to signal video formats explicitly just like movie files. Also, a number of applications now supports the capability (Affinity Photo and Pixelmator/Photomator).

<https://www.w3.org/TR/png-3/>

Single-Master HDR-SDR Workflow Recommendations

Single-Master HDR-SDR Workflow Recommendations

5.2. TIFF (ICC CICP Tag)

ICC Specification ICC.1:2022 / Profile Version 4.4.0.0 was released in 2022. Adobe Photoshop and MacOS recognizes the tags if properly attached to a TIFF file.

Caveats:

- MacOS currently does not display the files correctly in the “Preview” app.
- MacOS currently does not use the full-range-flag in CICP and defaults to full-range always. We hope this will be addressed soon.
- Compressor and FinalCut Pro do recognize the HDR/SDR and color space signaling.
- Photoshop is using the floating point mathematics of the ICC profile and not explicit video transformations. Don’t expect all the plug-ins to work as expected just yet.

<https://www.color.org/specification/ICC.1-2022-05.pdf>

5.3. Full Range vs Narrow Range images

PNG and TIFF still image files are typically use the RGB color representation. RGB files are typically stored in full range. What does that mean? It means that black is stored with a code value of “0”(zero), or the lowest digital value possible. Peak white is stored with the very highest digital code value (dependent on bit depth: 8,10,12, or 16 bit).

Y_CB_R video is typically used for motion video. Motion video is often compressed. Compression can have processing artifacts or errors that can be represented as values above peak white. Clipping these artifacts in the video can cause additional artifacts which are not desirable. This is why video has a headroom range below black and above peak white (also known as undershoot and overshoot) where these errors can be represented without clipping.

Since RGB files are typically uncompressed or lossless compressed in PNG and TIFF, the headroom range was often not represented but there are instances where the headroom is valuable. A good example would be test patterns which need to represent super white (above peak white) and super black (below black).

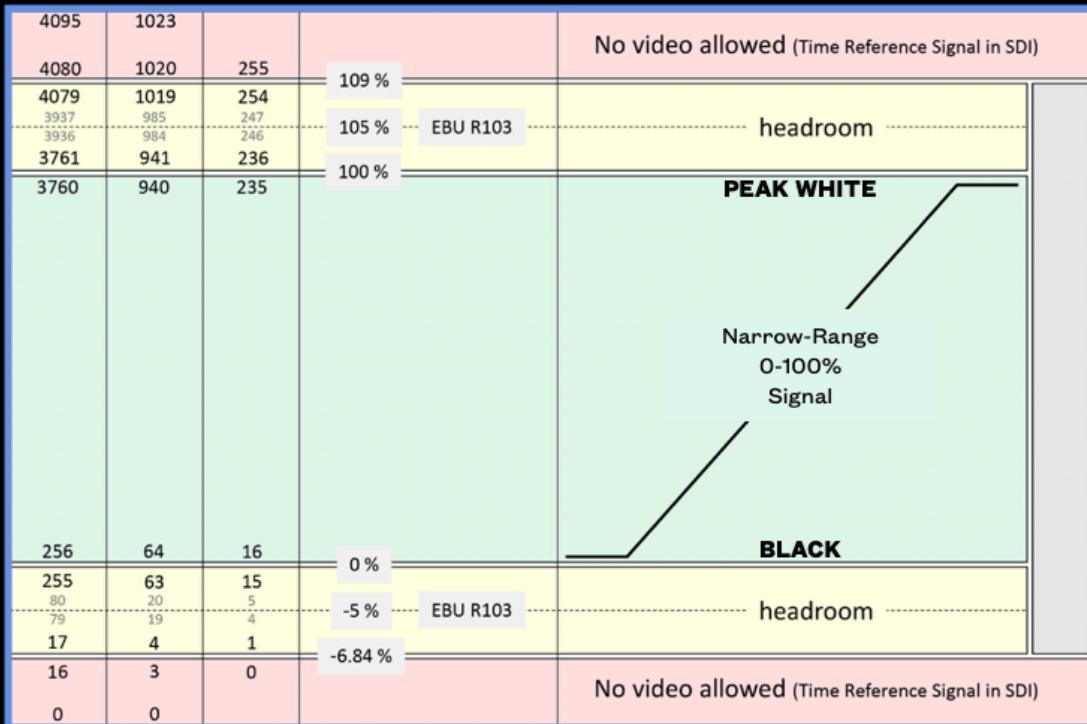
The graphic on the next page describes how full range and narrow or limited range images are represented digitally.

Image/Video Signal Ranges

Full Range



Narrow Signal Range



Single-Master HDR-SDR Workflow Recommendations

ANNEX 1: The Strategy Around NBCU LUT Conversions

The focus of the entire conversion effort is to maintain the original artistic intent such that the SDR derived from the NBCU LUT compared side-by-side is consistent with the HDR until the point where the advantages of HDR are realized even with a reduction of dynamic range in the converted SDR.

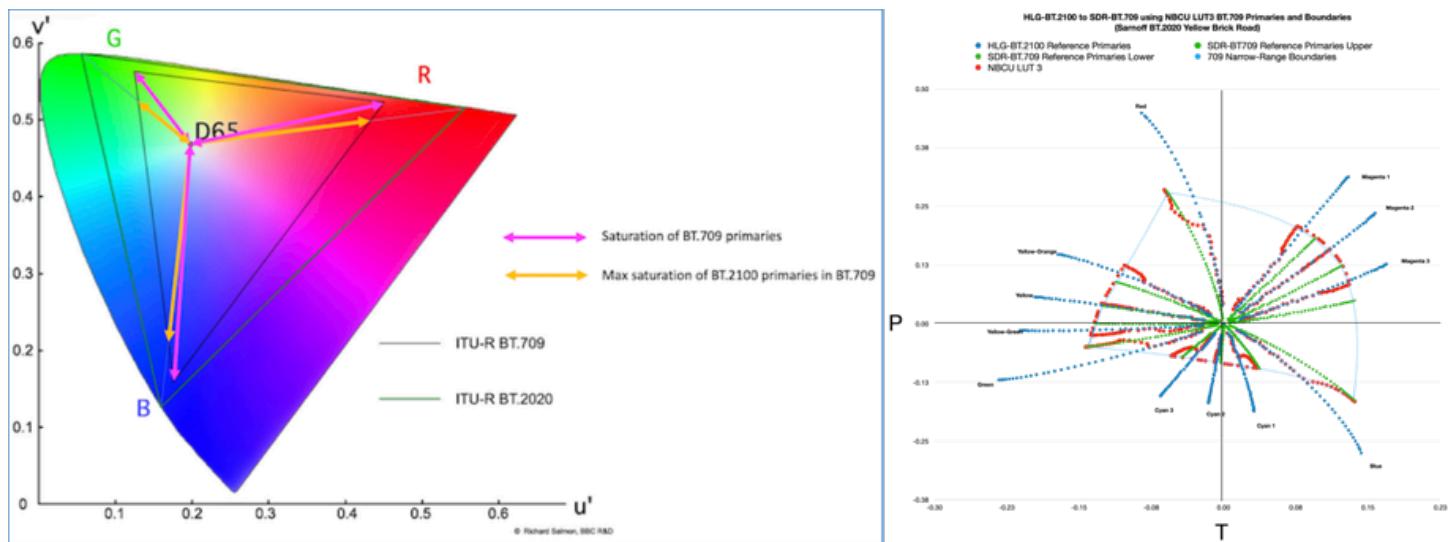
For HDR to SDR conversions there are several key characteristics that we adhere to:

For Light:

- SDR BT.709 content round-tripped through HDR returns to SDR imperceptibly from how it started. The color is consistent to the original and the reduction in the luminance isn't noticeable.
- The conversion uses a knee that is natural and provides appropriate latitude for live video shading while preserving highlights in SDR workflows that don't exceed 100% signal level.
- Attention has been placed on the mid-tones so that they remain at consistent light levels throughout the conversion.

For Color:

- BT.2020 colors inside the BT.709 triangle remain unchanged when mapped back to SDR.
- Content with BT.2020 colors that originate outside of the 709 boundary are mapped back into 709 in a manner that is as consistent to the original as possible. The illustration below shows that by using these techniques, we can fully saturate each color in SDR by slowly following the edge of the 709 color space during remapping.



Color filtering strategies to preserve original colors where possible when mapping BT.2020 to BT.709

During the creation of these LUTs an objective color metric measurement system (ITU-R BT.2124) and toolset has been utilized to plot various conversions and measure their color and light-level accuracies. An example is included in the T/P color plot above. By utilizing BT.2124, in combination with a set of test patterns that encompass the range of available color and light levels, we are able to drive the development of the color mapping strategies behind the LUTs.

Single-Master HDR-SDR Workflow Recommendations

ANNEX 2: 3D Cube Look-Up-Tables (3D-LUT)

3D-LUTS are the most common and efficient way to convert between HDR, SDR and different color spaces and transfer function curves.

In order to guarantee that the NBCU LUTS are accurate, we've collaborated with experts to develop **objective color metrics tools (using BT.2124)** that mimic the human visual systems or show absolute color values ($u'v'$). Both are important to quantify. The perceptual metrics differ from absolute mathematical comparisons that don't take into account how the human visual system perceives color and light.

The set of tools allow us to design and qualify conversions in hardware and software as well as detect issues that need to be fixed or optimized. [ITU-R BT.2124](#) techniques allow us to translate perceptual characteristics of color and light into graph-able results. Perceptual effects can alter production decisions, especially when HDR and WCG are introduced.

Figure 6a is a visualization how a 3D CUBE LUT works. The input samples create perfectly equidistant points within an RGB 3D cube. A 3D CUBE represents all the points of both color and light represented by values between zero(0) and one(1). The conversion LUT([Figure 6b](#)) represent those same points after they've been moved to new locations. A LUT provides the new locations for each point (the conversion).

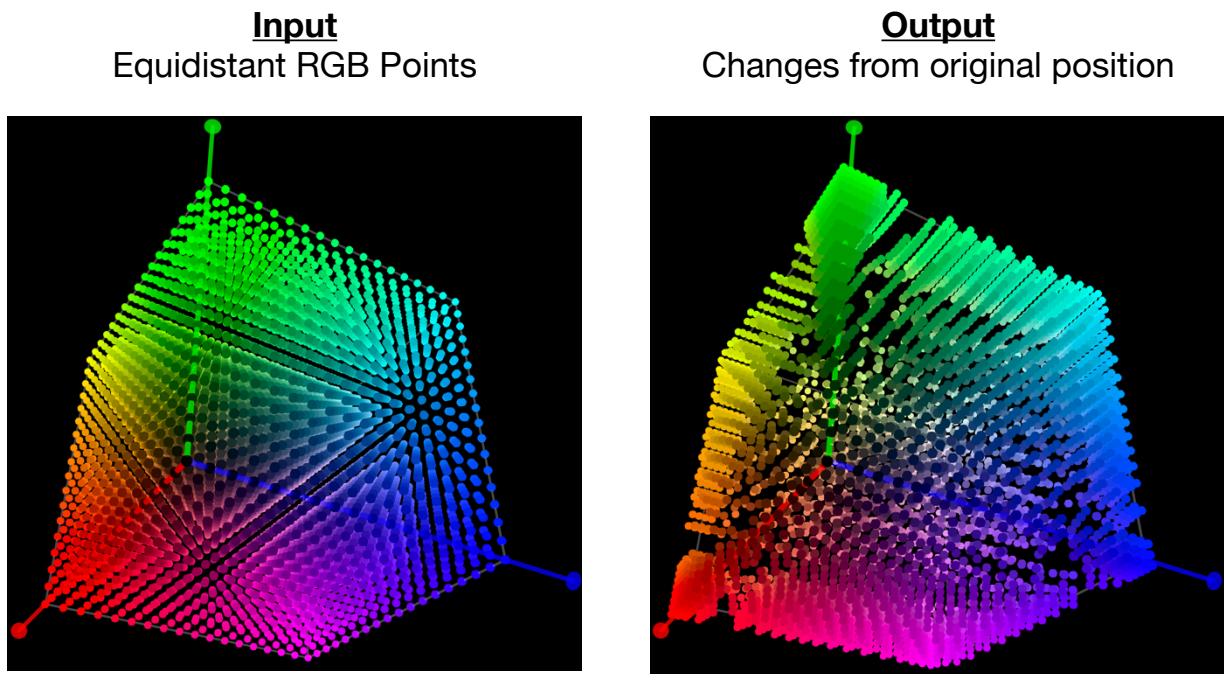


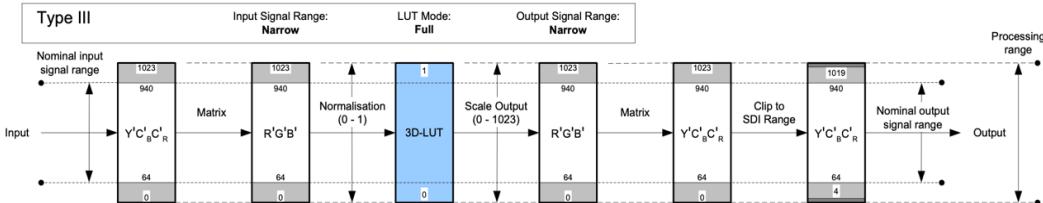
Figure 6a

Figure 6b

Single-Master HDR-SDR Workflow Recommendations

Look-Up-Tables can come in several different varieties that process different signal ranges. The BBC has labeled the different LUTs as “Type I, II, III”. All NBCU LUTS are “Type III”.:

- **Type III LUTs** - Processes narrow/legal range signals with extended range support (also known as super-white or sub-black). Narrow range in the 10-bit code range define video black at 10-bit code value 64 and “nominal peak level” or “peak white” at 10-bit code value 940. The nominal levels in a narrow range signal are also represented in a video waveform (scope) as 0-100% or 0-100IRE.



GRAPHIC COMPLEMENTS OF BBC

- **Cube LUT Types** - NBCU LUTS are supplied in Adobe, DaVinci Resolve 17 and DaVinci Resolve 3D Cube LUT formats.
- [EBU r103](#) has more information on the usage of narrow range, nominal signal levels and “excursions” above 100% signal level.
- **Caveats** - Some hardware or software require that a CUBE LUTs “TITLE” parameter be commented-out in a “Cube LUTS” text file. Add a “#” sign (without quotes) before the TITLE in order for the parameter to be ignored

3D LUT Interpolation Modes

LUT Interpolation Modes - Hardware and software use interpolation to determine values that are in-between the conversion points defined in a CUBE LUT. Through testing we were able to determine that to support our sophisticated gamut and luma compression in the down-mapping LUTS, **Tetrahedral interpolation** must be used to avoid artifacts.

The “sawtooth” artifact in Figure 8a is produced by trilinear interpolation. This is observed in the waveform display using a simple gray ramp with “highlight knee” used in the **NBCU HDR to SDR LUT** conversion. The waveform display (Figure 8b) shows the same knee with a smooth ramp produced by tetrahedral interpolation.

Single-Master HDR-SDR Workflow Recommendations

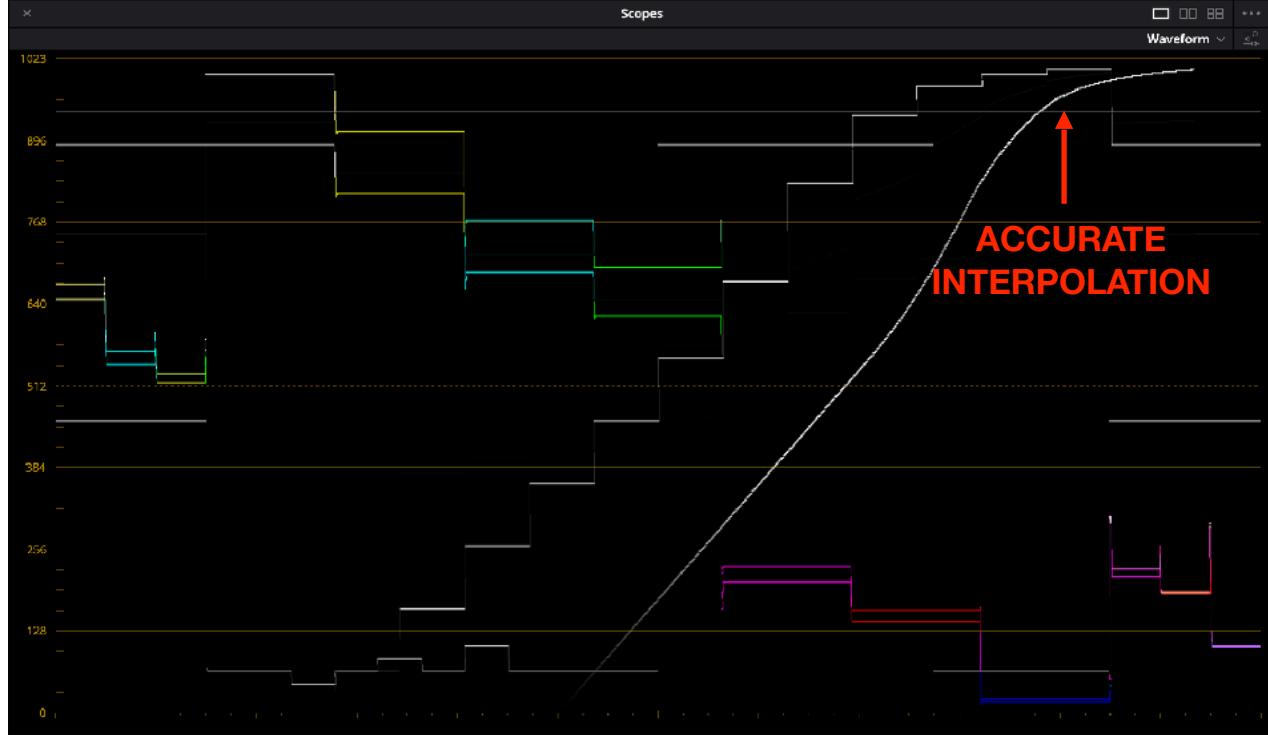


Figure 8b - Tetrahedral LUT Interpolation

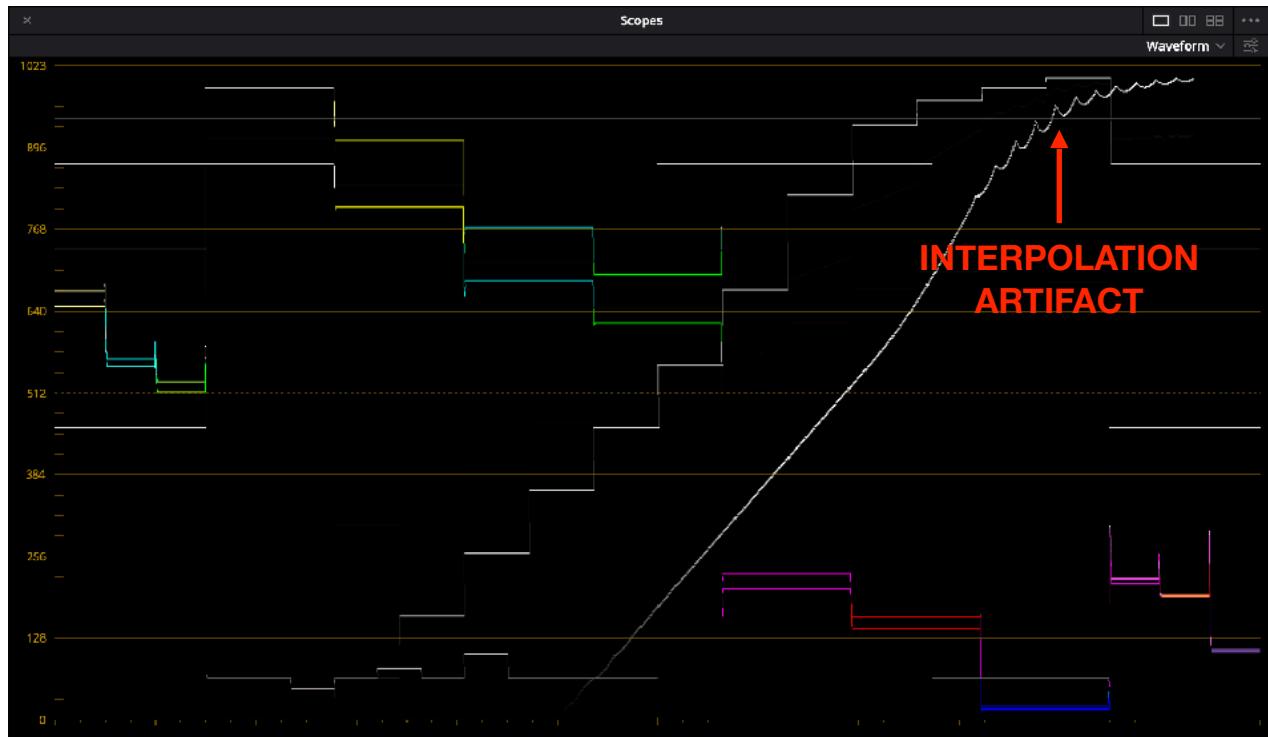


Figure 8a - Trilinear LUT Interpolation

Single-Master HDR-SDR Workflow Recommendations

ANNEX 3: Shading Detail

Single-Master HDR-SDR camera shading benefits by understanding the relationship of HLG levels in a scene. These levels have been studied are available in the ITU Recommendations of BT.2408 (see table below)

| HLG Video Levels (Display @ 1,000nits) | | |
|--|--------------------------|-----------------|
| | nits(cd/m ²) | % of HLG Signal |
| Grey Card (18%) | 26 | 38 |
| Greyscale Chart Max (90%) | 179 | 73 |
| Reference Levels | | |
| HDR Reference White (100%) | 203 | 75 |
| Diffuse White | | |
| Graphics White | | |
| Type 1-2 Light skin tone | 65-110 | 55-65 |
| Type 3-4 Medium skin tone | 40-85 | 45-60 |
| Type 5-6 Dark skin tone | 10-40 | 25-45 |
| Grass | 30-65 | 40-55 |

Setup

- HDR Camera settings:** Our suggestion is that Sony camera SDR differential gain should start around **-10**. In our model we don't utilize the SDR output of the CCU, this setting only affects the viewfinder and can be adjusted to aid the camera operator.
- Predictive LUT:** Shaders should use **NBCU LUT3** as a "predictive LUT" for previewing SDR output to transmission.
- HLG displays settings:** Video format should be set to [**HLG-BT.2100**](#) (**which utilizes BT.2020 color space**).
- SDR Display Settings:** When working in this environment we have found it's beneficial for the SDR monitoring to be set such that display brightness is 203nits. This provides for consistency between the 75% anchor point in HDR and the resultant SDR. For Sony reference displays, a SDR **User Preset** contrast setting can be adjusted to achieve this:

| Sony Display SDR Mode Contrast Settings | | | | | |
|---|-----------|-----------|-----------|----------|----------|
| | BVM-HX310 | PVM-X2400 | PVM-X1800 | BVM-X300 | BVM-E171 |
| Contrast Value | 812 | 812 | 812 | 812 | 2030 |

Single-Master HDR-SDR Workflow Recommendations

Setting HDR Camera Levels

- **Diffuse White:** defined as a large matte-white object like a white jersey or tee-shirt.
 - In a live-linear HLG production, diffuse white should be set at around 75% signal level (203nits). This is easily identifiable in a waveform monitor.
 - **Camera Charts:** Diffuse white would be the 100% chip on a camera chart.
 - **Diffuse-White** acts as an “**anchor point**” around which the rest of the production images are built.
- **Highlights:** The additional dynamic range available in HDR is known as highlights. On a waveform monitor this energy is represented from 75% to 100% of the HLG signal level. The subject of the composition is generally located below the anchor point but this will change scene by scene.

Setting SDR Camera Levels

- SDR cameras are shaded thru **NBCU LUT2 (SDR-to-HLG using scene light)**. Scene-Light conversion matches SDR cameras with native HLG cameras that have a slightly different “look”. Once they are converted to HLG, the bulk of the energy will be contained below the 75% anchor point.

Monitoring Graphics Video Levels

- **Graphics-White:** Graphics are currently produced in SDR content with a peak at SDR-100% signal level. **NBCU LUT 1** maps graphics to the recommended HDR graphics-white level of 203nits (75% signal level or 75IRE in HLG).

Monitoring SDR Output Down-Mapped Quality

- When an HDR display is used as the primary shading display, we utilize **NBCU LUT 3 acts as a “Predictive LUT”** for monitoring the signal fed to an SDR display and SDR transmission (a legacy channel).
- Diffuse-White acts as an “**anchor-point**” for setting HDR camera levels which simultaneously produces SDR output through **NBCU LUT3**. The “**Predictive LUT**” provides the ability to determine the relationship between optimal HDR levels and the derived SDR

Single-Master HDR-SDR Workflow Recommendations

ANNEX 4: Production and Distribution Video Formats

The NBCU production LUTS have been designed and tested using both objective perceptual and absolute color metrics. The goal has been to preserve the artistic intent during each stage of the conversion process. Basic concepts for signal flow:

- Every video signal entering production is normalized to [HLG-BT.2100](#).
- Every video signal entering distribution is normalized to [PQ10-BT.2100](#).
- HLG to PQ conversion is mathematically transparent and uses formulas defined in [ITU-R BT.2390](#).

5.1. Why Use HLG For Production?

HLG is the most common native HDR format used in broadcast production. HLG is universally supported by professional native-HDR broadcast displays, switchers, software and conversion devices. HLG is capable of being viewed on existing SDR displays with some level of backwards compatibility.

5.2. Why Use PQ For Distribution?

PQ preserves the capabilities of linear production which currently occurs at a peak of 1,000nits. PQ is the native HDR format used during cinema(film) mastering which can be mastered as high as 4,000nits. PQ enables both content types to be displayed on the same live-linear channel without changing the original artistic intent.

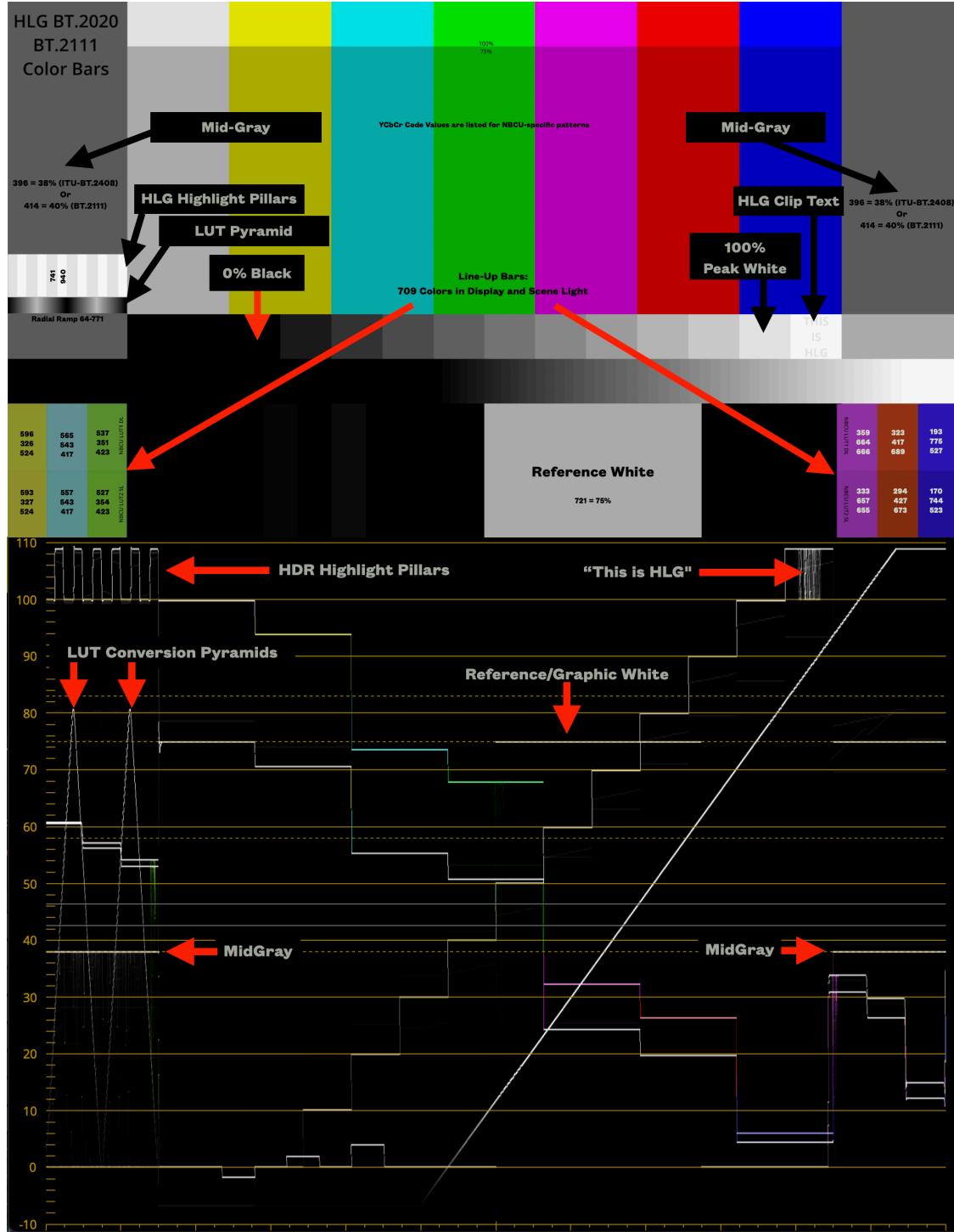
- PQ is the currently the most common format for streaming devices and services.
- PQ is the standardized HDR format for delivery to cable services in the United States (SCTE)
- PQ preserves an absolute brightness level to the consumer device which provides a more consistent method for preserving the focal point of the composition.
- PQ allows for additional saturation to be described. This is described in Section 7.5 of [ITU-R BT.2390](#).
- HLG to PQ conversion is mathematically transparent so there is no quality loss when converting between linear broadcast production and distribution. This is described in Section 7.2 of [ITU-R BT.2390](#).
- Converting HLG to PQ for distribution preserves HLG levels between 100-109% in PQ and therefore ensures delivery of this range to the home consumer display. HLG levels beyond 100% are often clipped in consumer displays.
- PQ can support more sophisticated tone-mapping formats such as HDR10, Dolby Vision and HDR10+ (static and dynamic methods).

ANNEX 5:

WAVEFORM MONITOR REFERENCE SCREENSHOTS

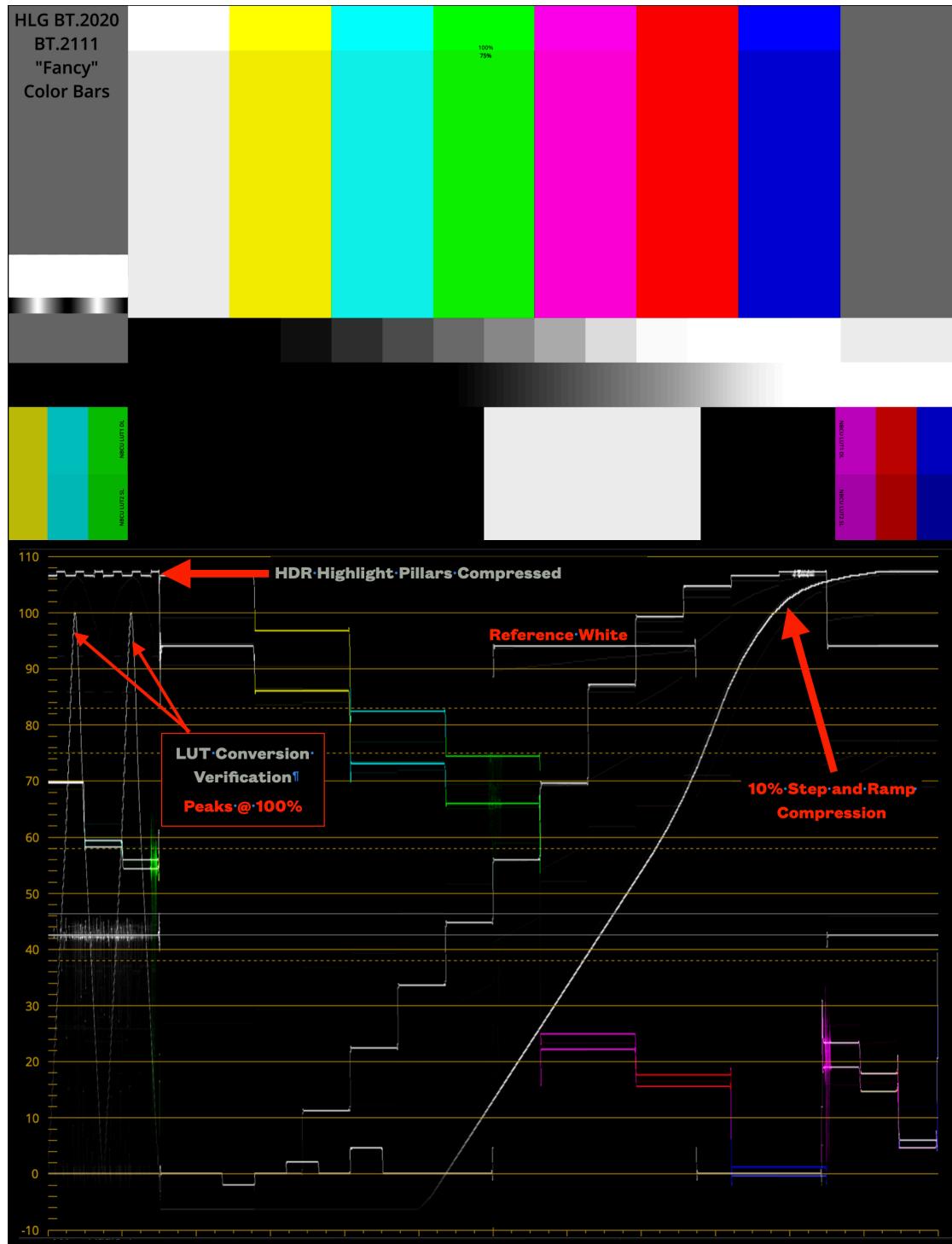
Single-Master HDR-SDR Workflow Recommendations

HLG “Fancy” NBCU Color Bars



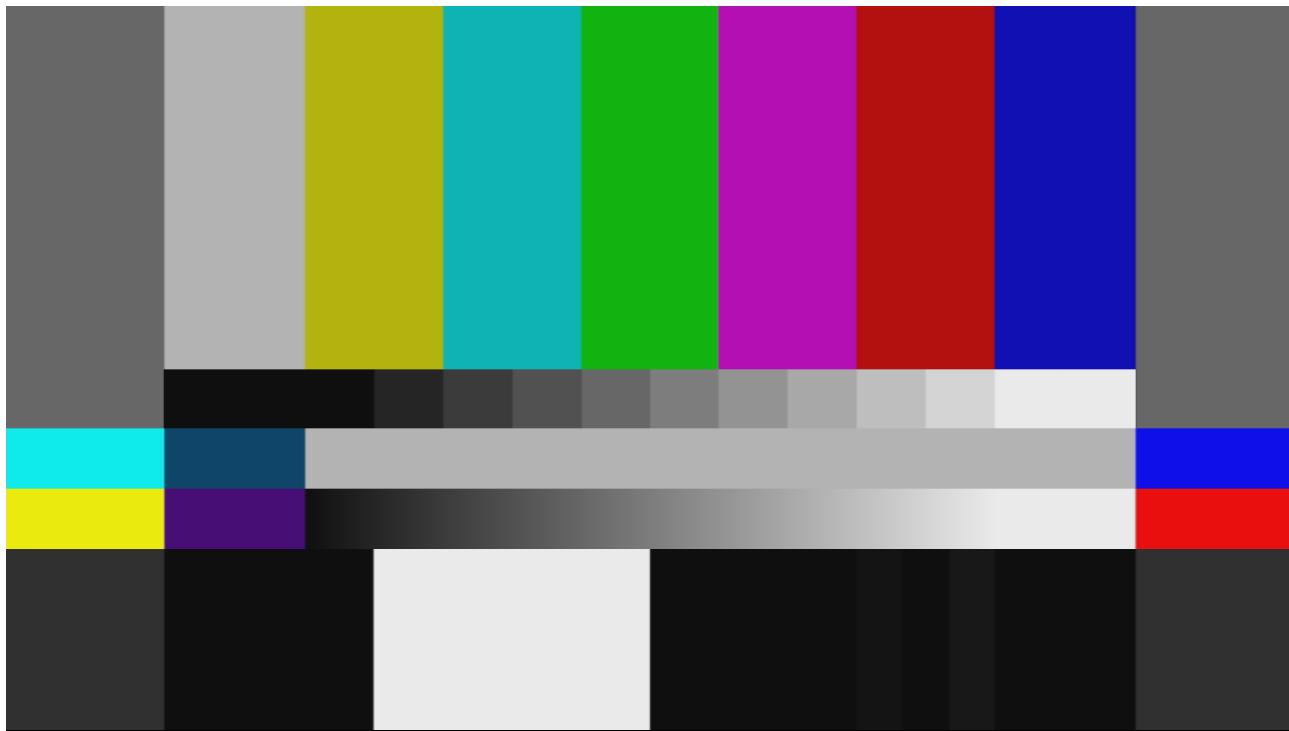
Single-Master HDR-SDR Workflow Recommendations

HLG to SDR (NBCU LUT 3) (Display-Light Direct down-mapping)

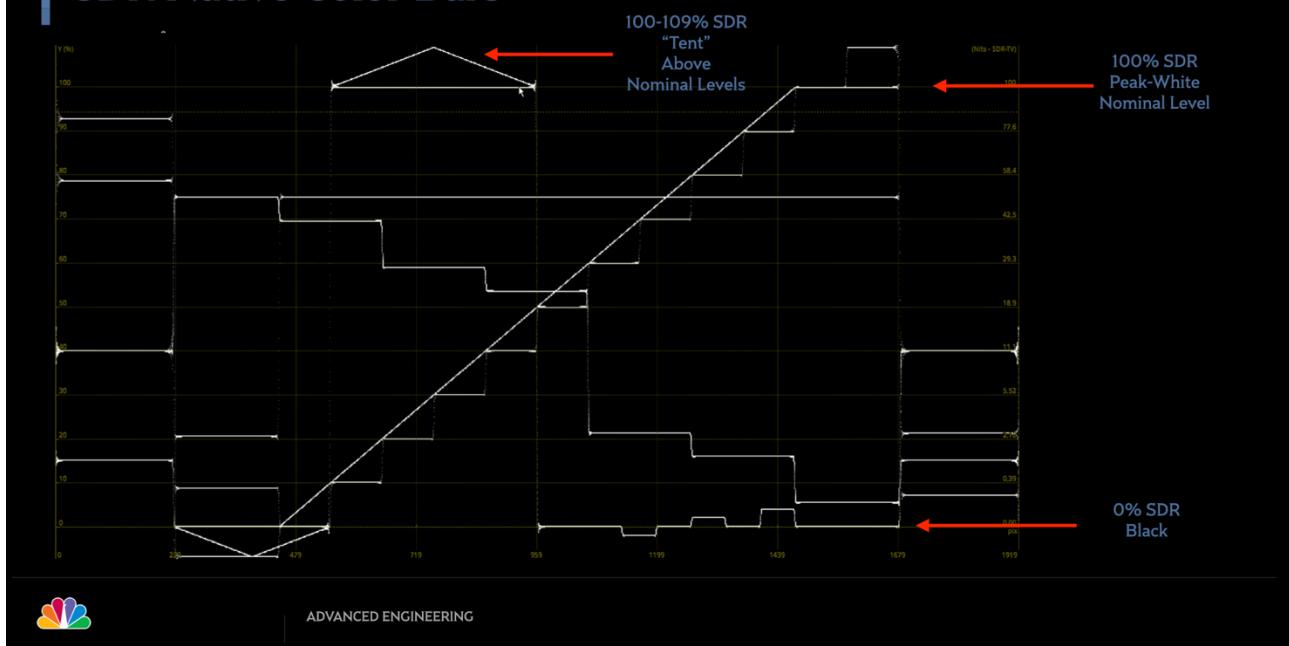


Single-Master HDR-SDR Workflow Recommendations

SDR Color Bars with Jacobs Ladder, Tent and Valley

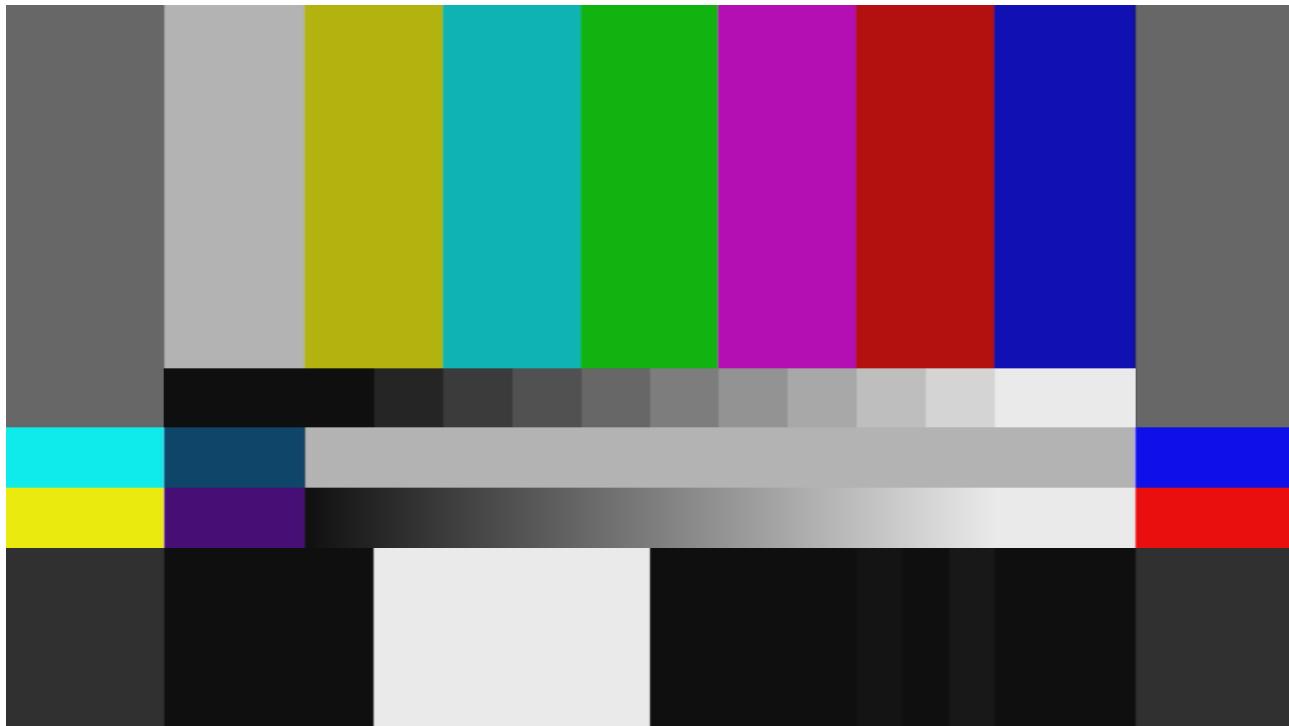


SDR Native Color Bars

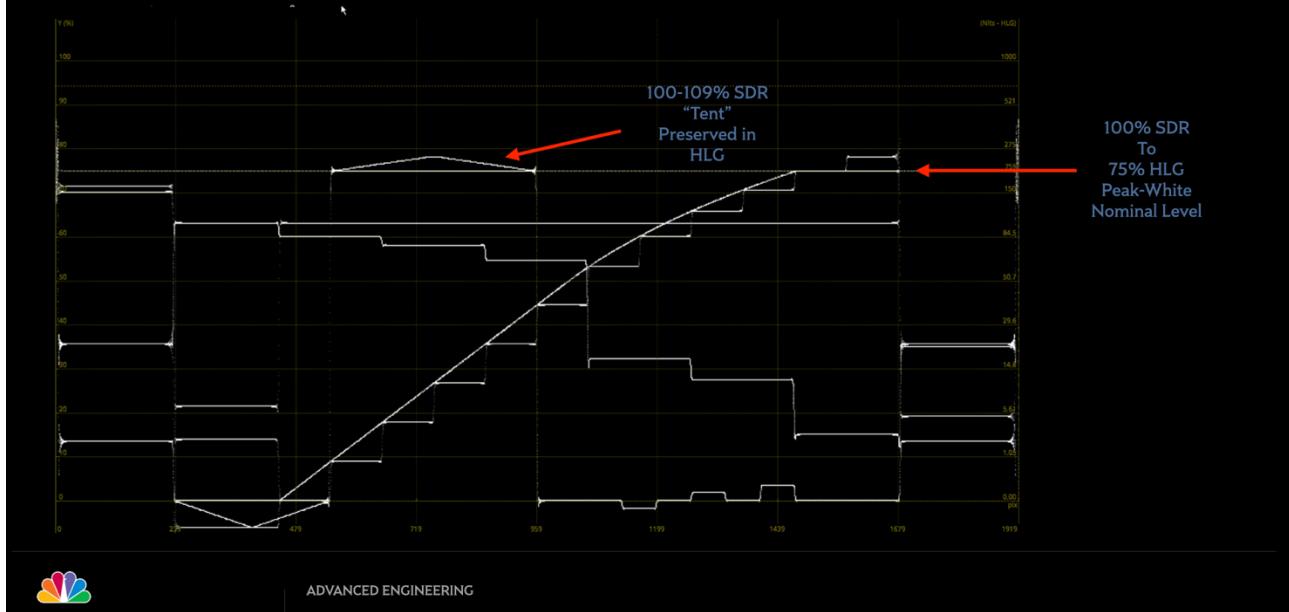


Single-Master HDR-SDR Workflow Recommendations

SDR-to HLG (NBCU LUT1) Color Bars with Jacobs Ladder, Tent and Valley

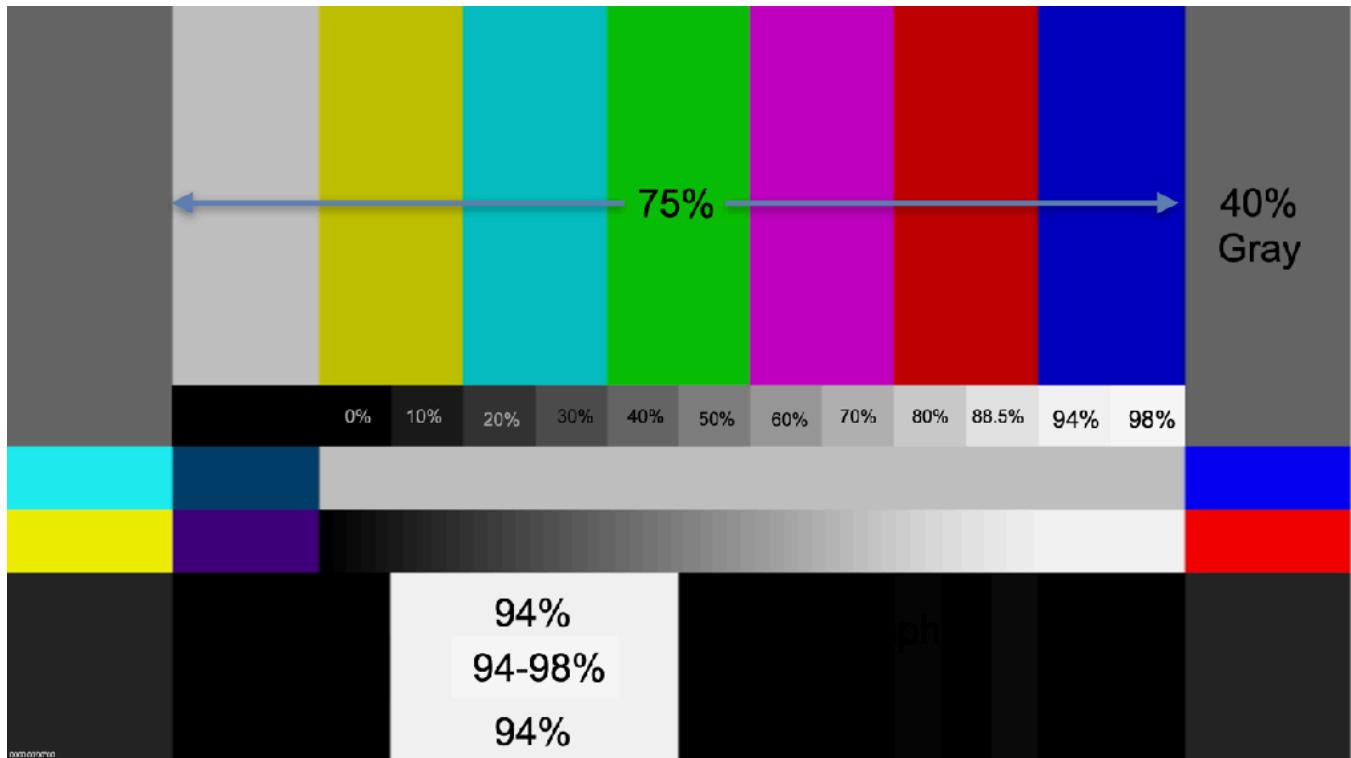


| NBCU LUT 1: SDR-to-HLG Color Bars

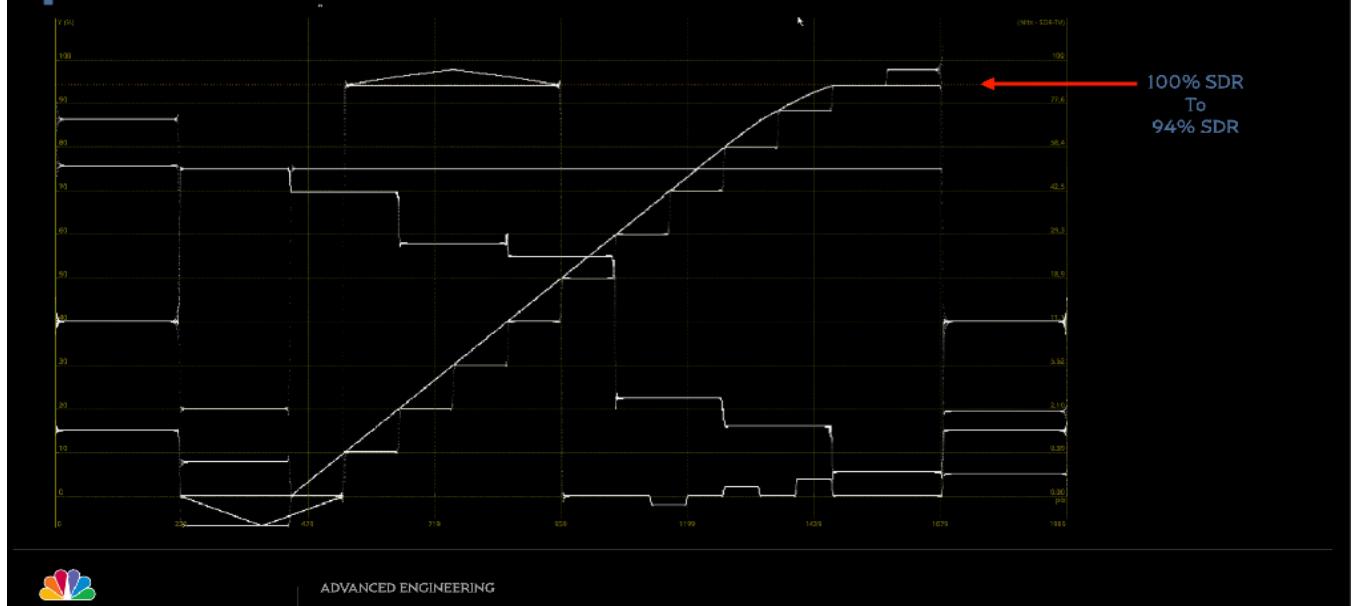


Single-Master HDR-SDR Workflow Recommendations

NBCU LUTs SDR-HLG-SDR Roundtrip BT.2111 SDR Color Bars



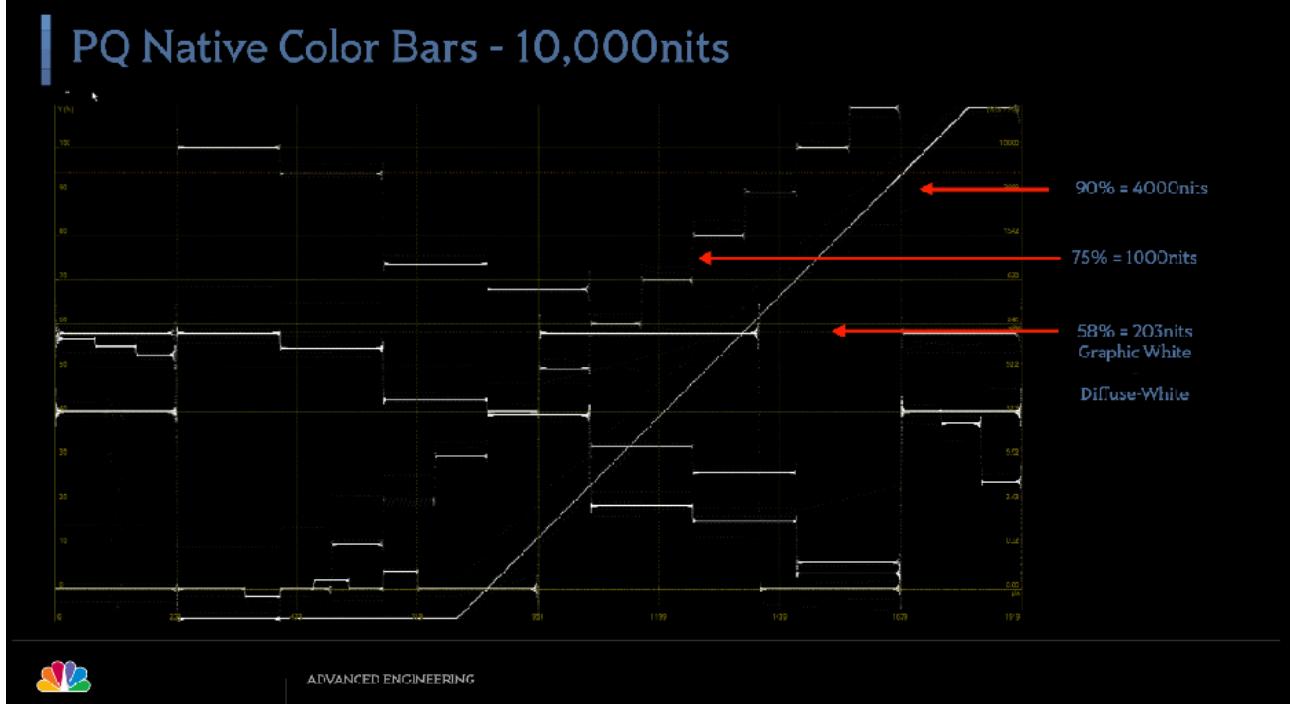
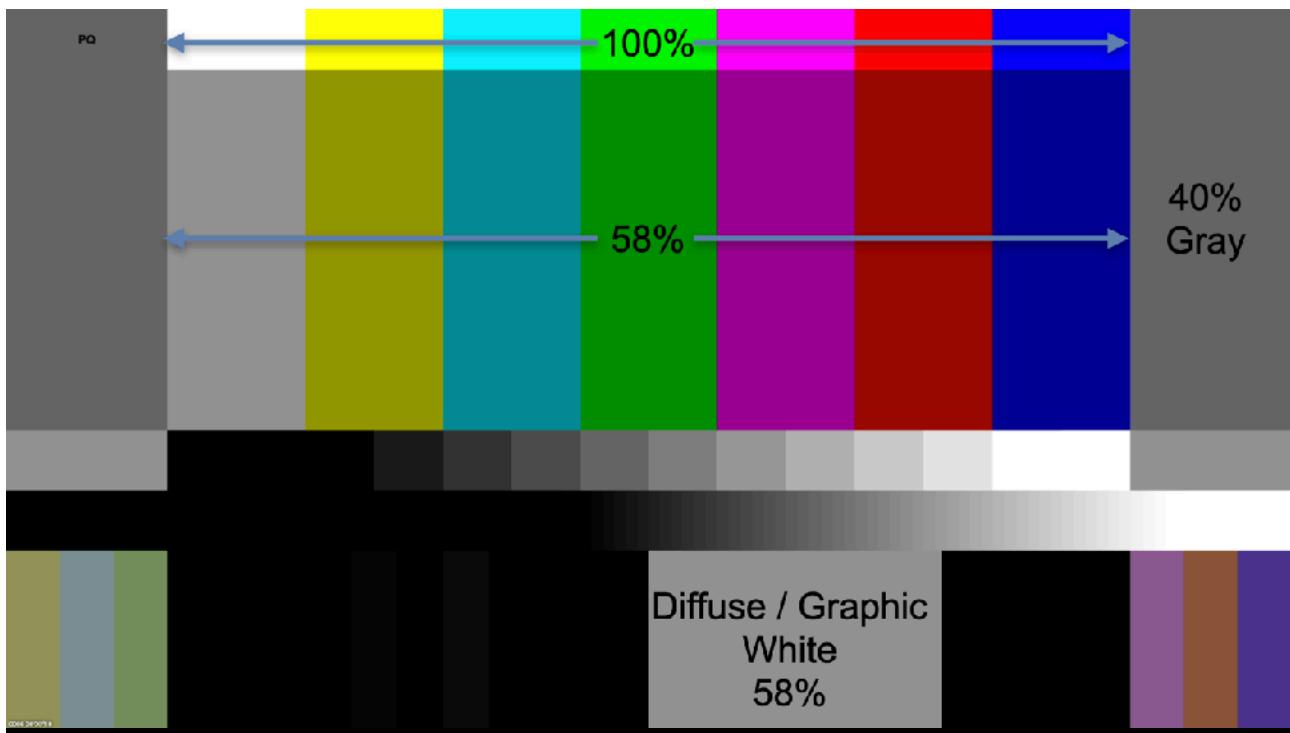
NBCU LUTs 1+3: SDR-to-HLG-to-SDR Roundtrip Light Levels



Single-Master HDR-SDR Workflow Recommendations

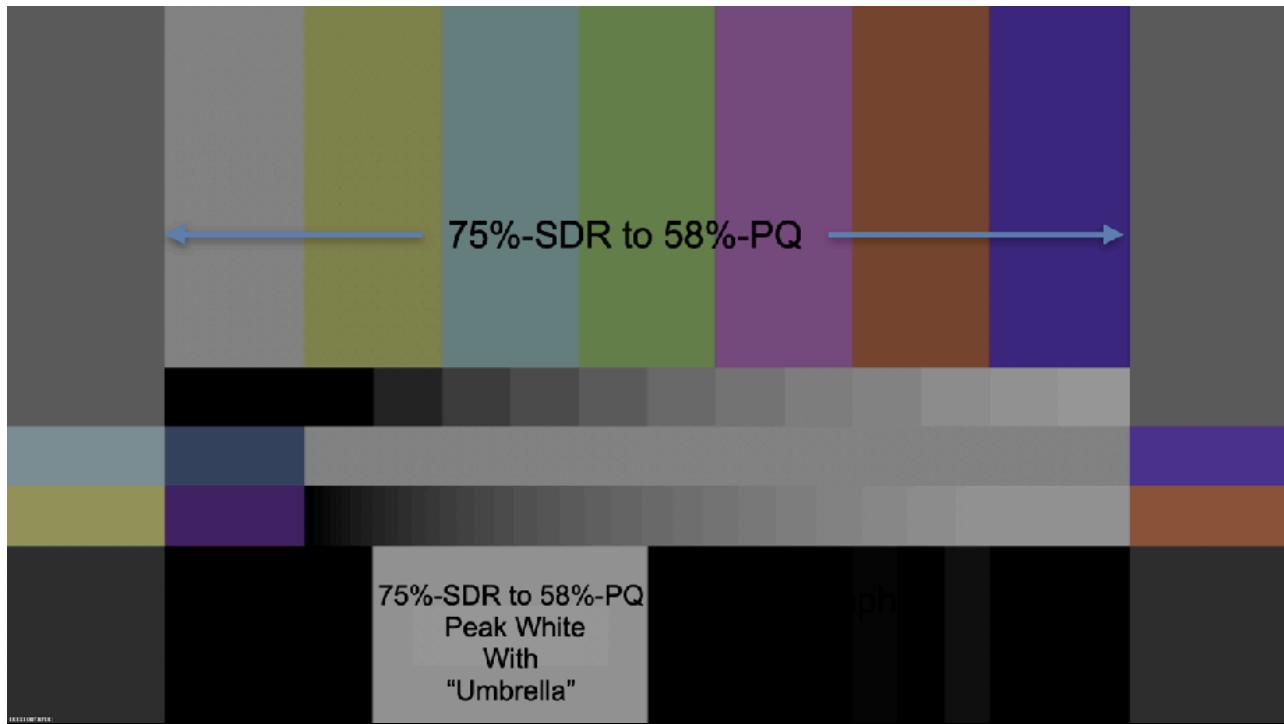
Single-Master HDR-SDR Workflow Recommendations

BT.2111 - PQ Color Bars

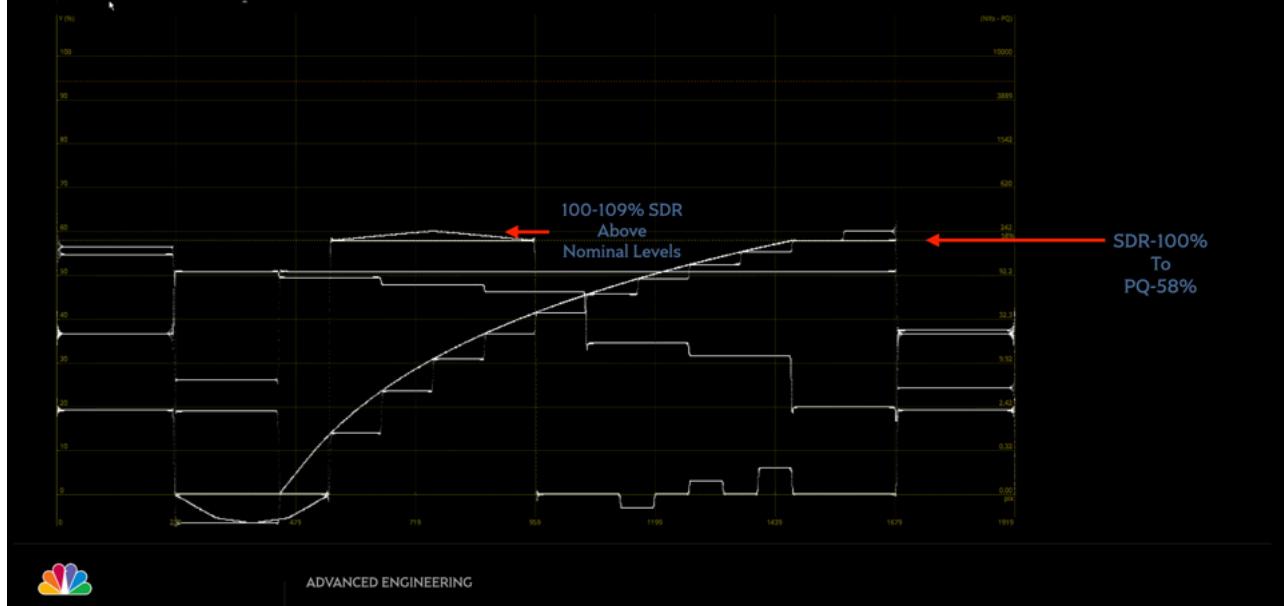


Single-Master HDR-SDR Workflow Recommendations

SDR to PQ - SMPTE Bars with Gray 10% Ladder

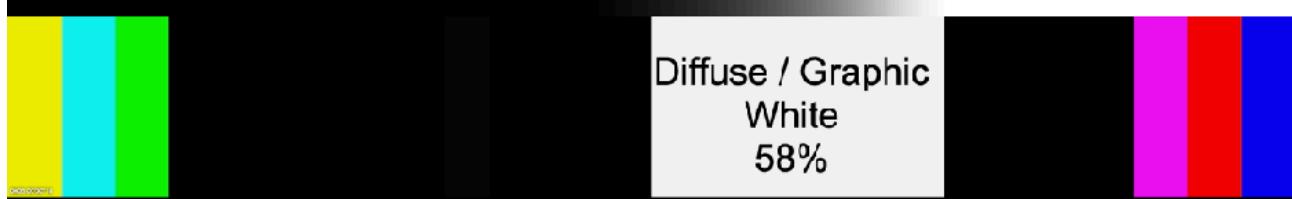
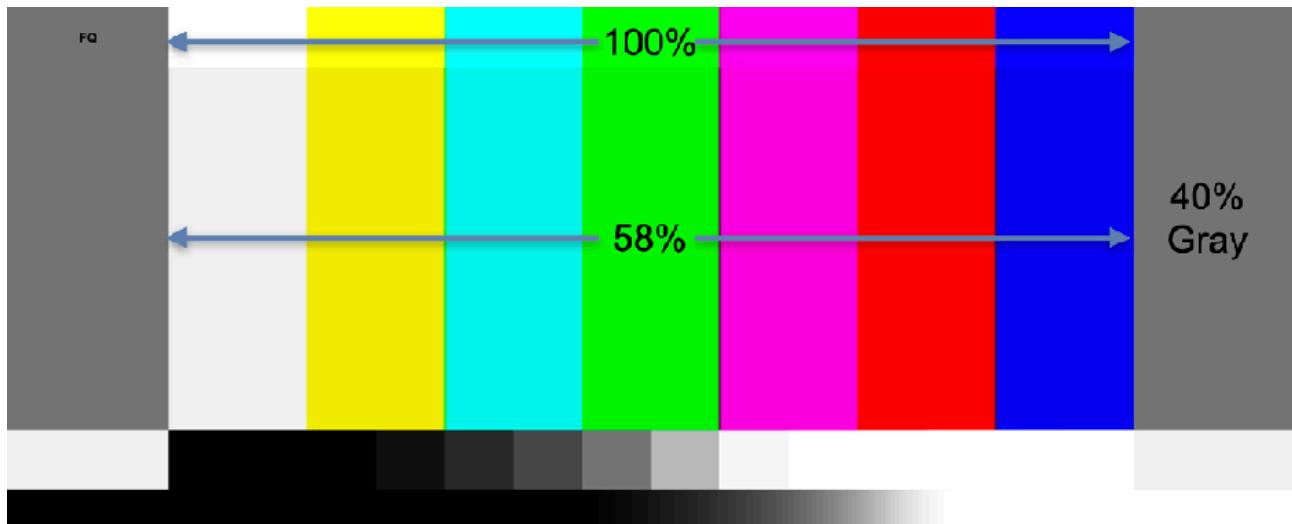


NBCU LUT4: SDR-to-PQ Light Levels

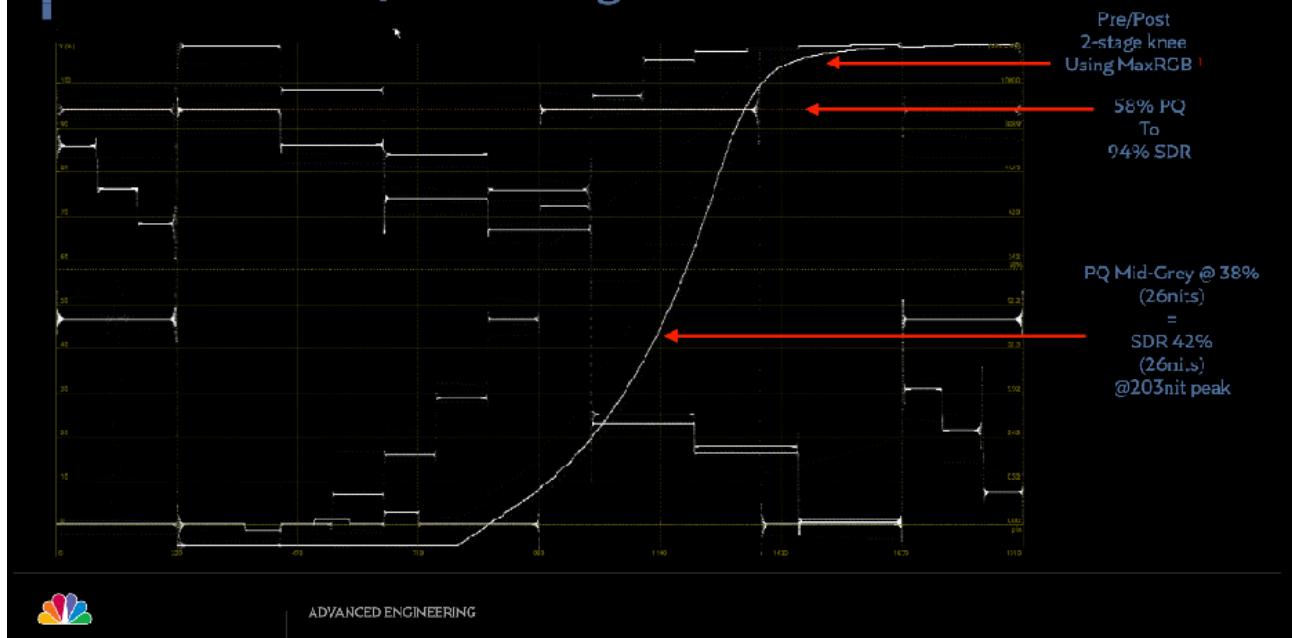


Single-Master HDR-SDR Workflow Recommendations

BT.2111 NBCU LUT 5 (PQ to SDR - Display Light)



NBCU LUT5: PQ-to-SDR Light Levels



ADVANCED ENGINEERING

ANNEX 6:

Objective Color

Metric

Measurement

Single-Master HDR-SDR Workflow Recommendations

This section will cover testing signal pass-thru or conversion using ΔE -ITP techniques defined in ITU-R BT.2124.

NBCUniversal has commissioned a number of color metric tools into a plug-in for the Video Player called “Vooya” for performing various objective color metric testing with ITP and $L^*u^*v^*$. These tools were developed to help the industry understand whether their devices are successfully passing or converting video signals (using LUTs or mathematical transforms) correctly.

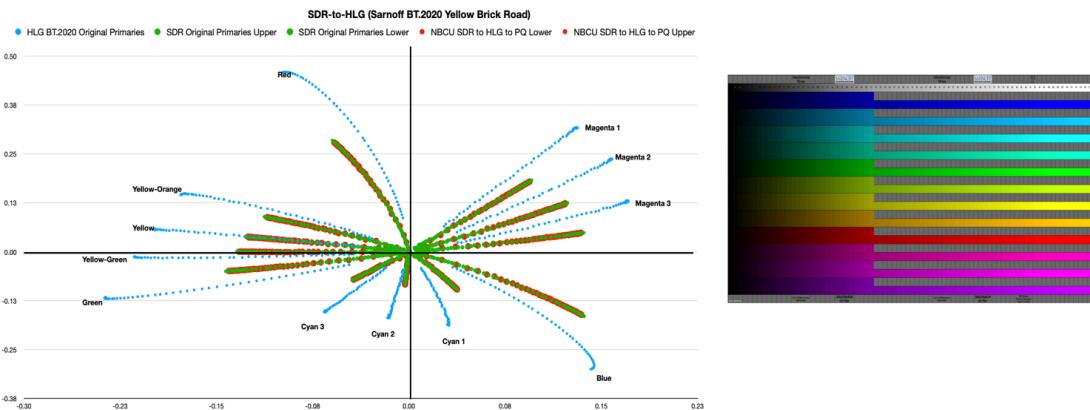
Basic instructions for the **objective metrics measurement tools** are listed under a Github repository located here:

<https://github.com/digitaltvguy/NBCU-UHD-HDR-SDR-Resources-Table-of-Contents>

Apple eBooks and PDF versions for Windows users are available.

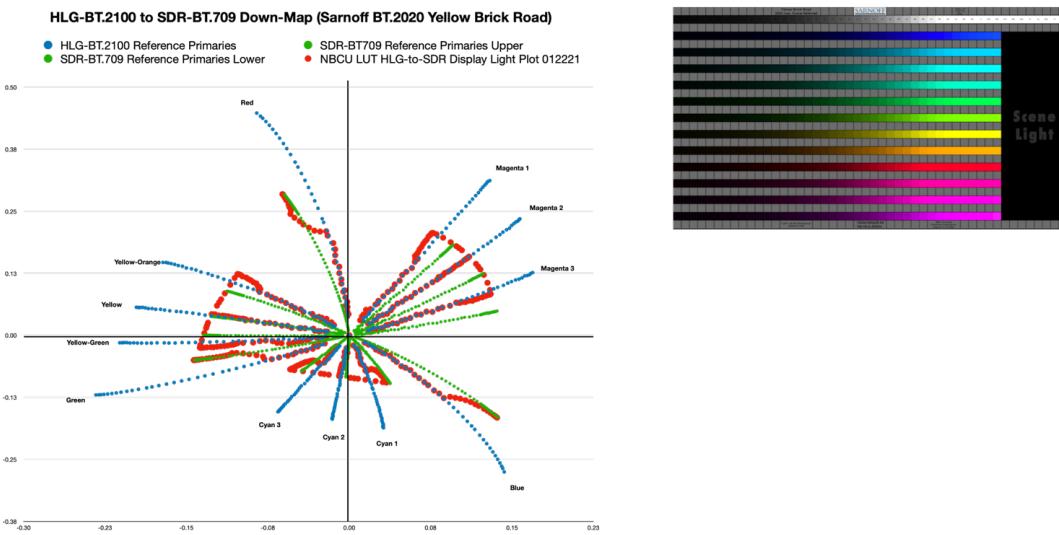
NBCU LUT 1: SDR to HDR Conversion

Original Colors in BT.709 are preserved into a HDR-BT.2020 container(Either HLG or PQ). There are no perceptible hue shifts.



NBCU LUT 3 & 5: HDR to SDR Conversion

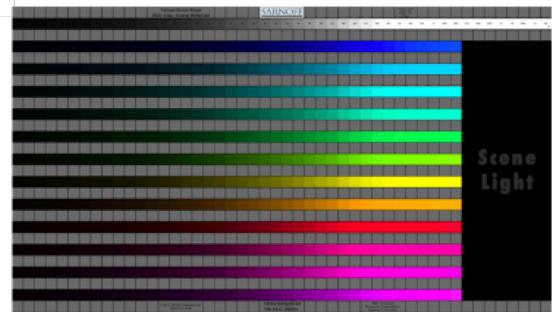
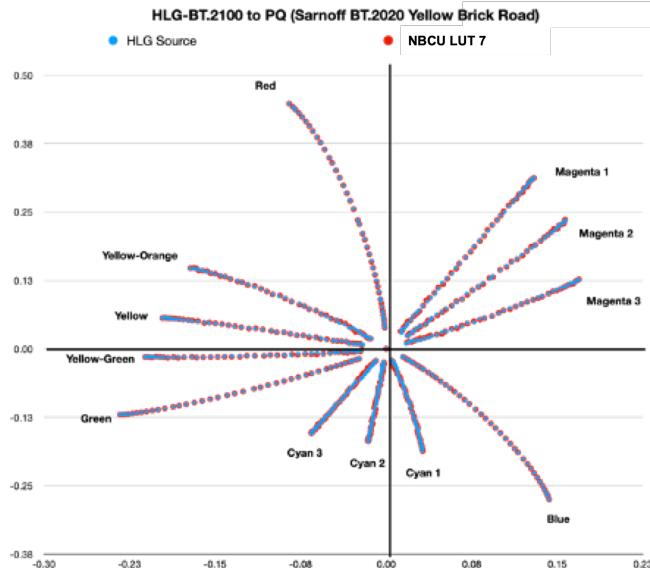
Original Colors in BT.2020 are preserved into SDR-BT.709 Container



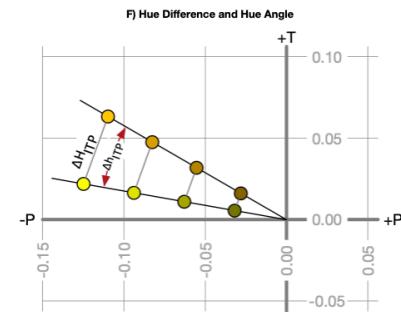
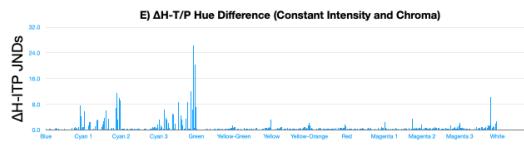
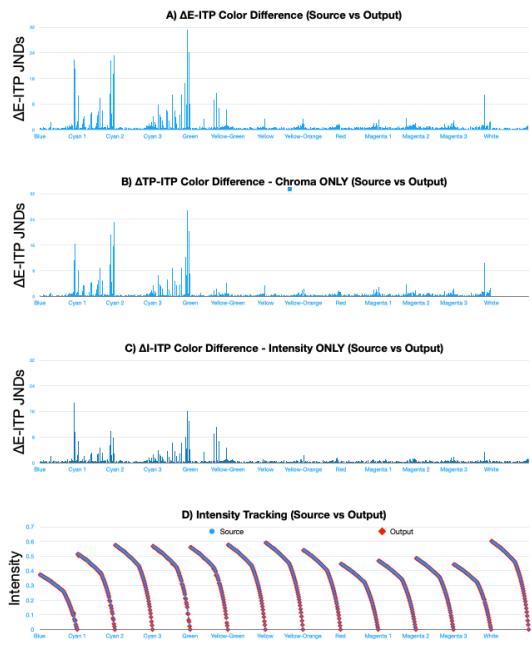
Single-Master HDR-SDR Workflow Recommendations

NBCU LUT 7: HLG to PQ Conversion

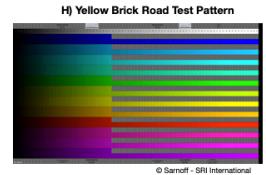
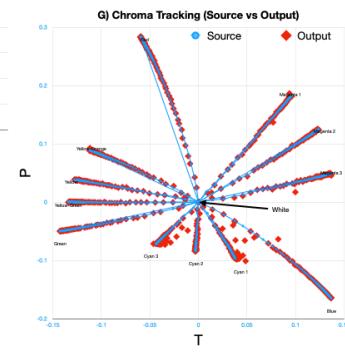
Mathematically transparent conversion.



- No visible hue shifts
- Perfect hue tracking



The samples in each color difference pair have the same chroma, for being the same distance from the origin. The hue angle difference Δh_{ITP} , in this illustration from yellow to yellow-orange, is constant for these pairs, but the hue difference ΔH_{ITP} increases proportionally to a pair's chroma.



ANNEX 7:

Signal Level Relationships

During Conversion

Single-Master HDR-SDR Workflow Recommendations

Single-Master live production requires that specific relationships be established between HDR and SDR levels. To create those relationships, we must define:

- Where conversions occur between different video formats (SDR, HLG, PQ).
- What “Anchor Points” are used to establish a relationship between the levels of one format to another. For the purpose of this document, we will use the most common anchor point between SDR and HDR which is 203nits or 75% ire in HDR.
- The assumption is that HDR displays are set for peak brightness of 1000 nits and SDR displays are set for a peak brightness of 203nits at 100% signal level.

GOALS:

- Convert all source formats to a single, internal format within each environment (Production=HLG) (Transmission=PQ).
- Production shall feed both the native HDR formats and the legacy SDR formats with the eventual goal of switching transmission to accepting a Single-Master deliverable as well.

On the next few pages, we will graphically explore the relationships between HDR and SDR when using the conversion LUTs.

Single-Master HDR-SDR Workflow Recommendations

a. SDR->HLG->SDR ROUNDTRIP MAPPINGS:

Figure xxx demonstrates how the signal levels are remapped

- **SDR to HLG - NBCU LUT 1+2:** SDR-100% signal level is converted to HLG-75%.
- **HLG to SDR - NBCU LUT 3:** HLG-75% is converted to SDR-94% with HDR highlights compressed between SDR_94-109% using a 2-stage knee.

SDR to HLG to SDR Roundtrip Anchor Points

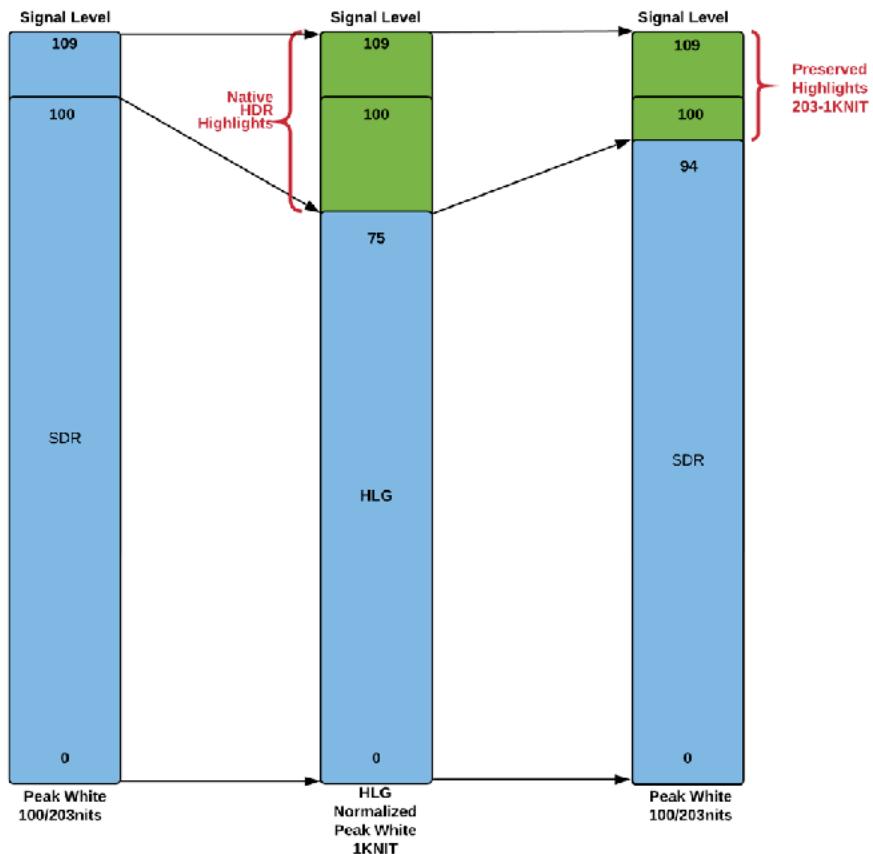


Figure 1

Single-Master HDR-SDR Workflow Recommendations

b. PQ MAPPINGS (SDR-PQ-SDR):

Transmission LEVELS (Roundtrip SDR-PQ-SDR):

Figure xxx demonstrates the signal levels in transmission.

- **SDR to PQ - NBCU LUT 4:** SDR-100% is converted to PQ-58%.
- **PQ to SDR - NBCU LUT 5:** PQ-58% is converted to SDR-94% with HDR highlights compressed between SDR_94-109% using a 2-stage knee.

SDR to PQ to SDR Roundtrip Anchor Points

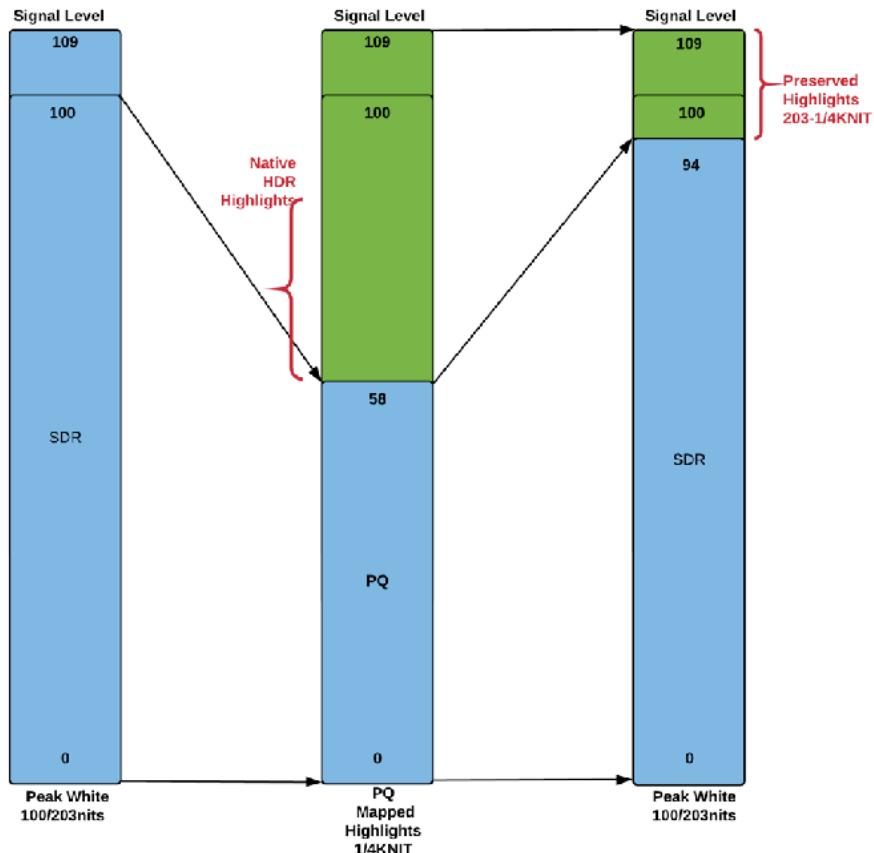


Figure 2

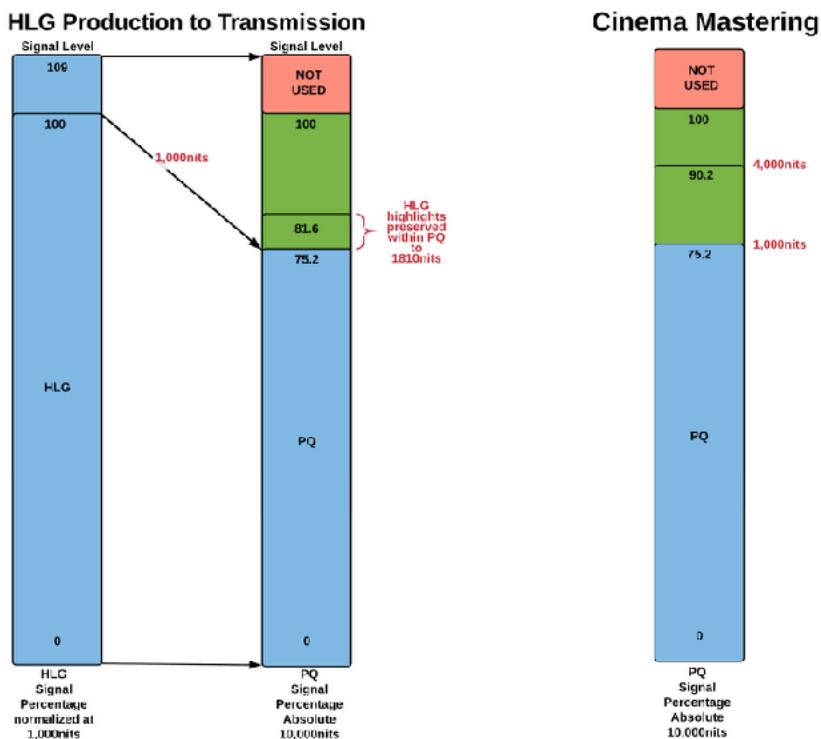
Single-Master HDR-SDR Workflow Recommendations

c. HLG -> PQ LEVEL MAPPINGS:

Native HDR Transmission LEVELS (HLG-to PQ and Cinema PQ):

To see how the signal levels are adjusted look at Figure xxx below to examine a full roundtrip thru production:

- **HLG to PQ - NBCU LUT 7:** Transparent conversion from HLG to PQ preserving both the look and absolute light levels.
- Cinema mastering levels remain intact.



Single-Master HDR-SDR Workflow Recommendations

d. NBCU LUT CONVERSION ANCHOR POINTS:

The tables on the following pages describe the primary “anchor points” (levels) broadcasters use during shading to make sure image levels between cameras are consistent as well as conversion to SDR. Single-Master production is dependent on keeping the anchor points consistent. All tables indicate percentages of signal level and/or nits.

In these tables, SDR peak white has an “adjusted” peak white level of 203nits (instead of 100nits). HLG and PQ Peak-White is assumed to be normalized at 1000nits excursions above 100% signal level are allowed in HLG and SDR.

Here are the most important reference levels that we will identify as defined in ITU-R BT.2408:

- **Graphic White:** 203nits.
- **Mid-Grey:** 26nits
- **Peak White:** Peak white defined at 100% signal level in each format.

| A. SDR-BT.709 to HDR-BT.2100 Display-Light | | | | |
|---|-------------------------|---|-------------------|-------------------|
| | SDR | | HLG (LUT1) | PQ (LUT 4) |
| Graphic White | 100% | = | 75%=203nits | 58%=203nits |
| Mid-Grey | 42.46%=26nits | = | 38%=26nits | 38%=26nits |
| Peak White | Normalized at 1,000nits | = | 75% = 1,000nits | |
| Highlights | 1000-1810nits | = | 75-82% | |

| B. SDR-BT.709 to HLG-BT.2100 Scene-Light | | | | |
|---|---------------|---|-------------------|--|
| | SDR | | HLG (LUT3) | |
| Graphic White | 100% | = | 75%=203nits | |
| Mid-Grey | 42.46%=26nits | = | 38%=26nits | |
| | | | | |

| C. HDR-BT.2100 to SDR-BT.709 Display Light | | | | |
|---|--------------------|-------------------|---|--|
| | HLG (LUT 3) | PQ (LUT 5) | | SDR 203nit Peak White (Display) @ 100% Signal Level |
| Mid-Grey HDR@26nits | 38% | 38% | = | 42.46% = 26nits |
| Graphics / Diffuse White HDR@203nits | 75% | 58% | = | 94% = 176nits |
| HDR-to-SDR Peak White HDR@289nits | 81% | 62% | = | 100% = 203nits |
| Highlights HDR@1000nits | 100% | 75% | = | 107 = 237nits |

Single-Master HDR-SDR Workflow Recommendations

ANNEX 8: ITU-R BT.2408 Workflow Drawing

These drawings are now part of ITU-R BT.2408: ANNEX 10.

Please refer to them here: <https://www.itu.int/pub/r-rep-bt.2408> and scroll down to Annex 10. [ITU-R BT.2408-8](#) is the earliest version you should reference.

ANNEX 9: ITU-R BT.2408 Conversion Detail

These drawings are now part of ITU-R BT.2408: Section 5.1.1.

Please refer to them here: <https://www.itu.int/pub/r-rep-bt.2408> and scroll down to Section 5.1.1 and also Annex 9. [ITU-R BT.2408-8](#) is the earliest version you should reference.

**SUBJECTIVE CONVERSIONS MAY USE DIFFERENT PERCEPTUAL SPACES,
GAMUT AND LUMA COMPRESSION OR RE-ORDER PROCESSING**

Single-Master HDR-SDR Workflow Recommendations

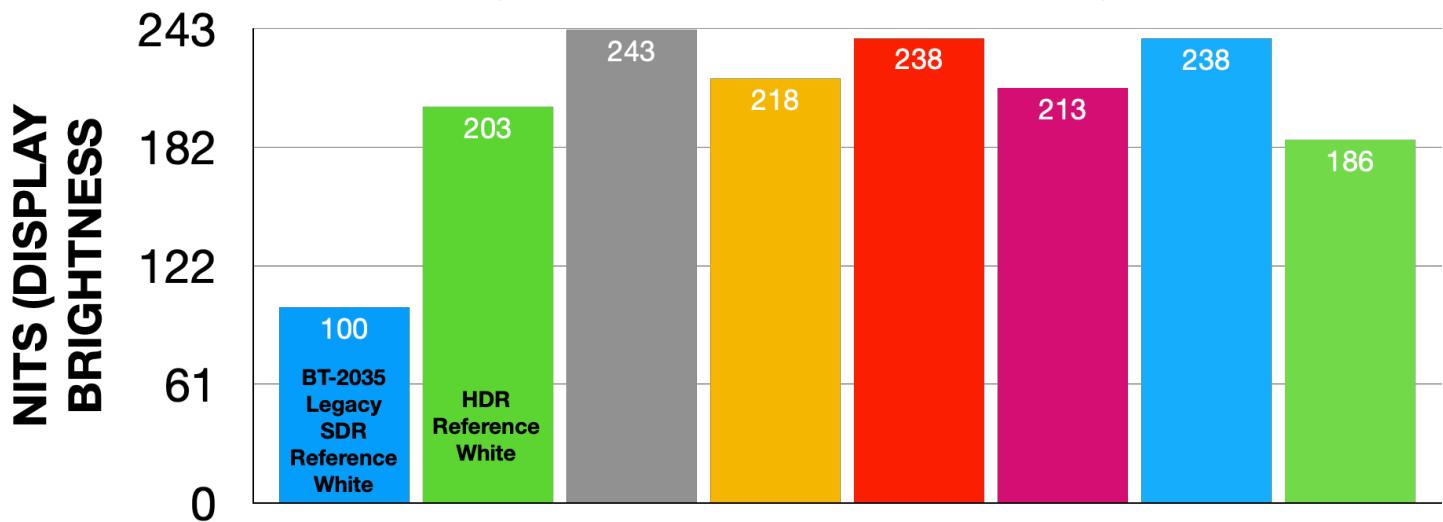
Annex 10: NABA-NBCU-MovieLabs TV Luminance Survey Summary

| SDR DISPLAY LUMINANCE AND "EFFECTIVE GAMMA" IN DIFFERENT PICTURE MODES | | | | | | | | | | | | | |
|--|---|---------|----------------------|-----------------|-----------------|---------------------------------------|-------------------------|---------|----------|---------------------------------|--|--|--|
| Picture Modes | Cinema | | | Filmmaker Mode | | | Factory | | | TV's Manufactured At/After 2016 | | | |
| | LCD Full Screen | LCD L32 | OLED L32 | LCD Full Screen | LCD L32 | OLED L32 | LCD Full Screen | LCD L32 | OLED L32 | | | | |
| Display Type | | | | | | | | | | | | | |
| Pattern Size | | | | | | | | | | | | | |
| Average Peak White | AVG Nominal Peak White | 228.65 | 242.52 | 217.50 | 247.45 | 238.23 | 212.50 | 241.87 | 237.91 | 186.00 | | | |
| Max Peak White | MAX Nominal Peak White | 405.90 | 416.00 | 234.00 | 397.50 | 390.00 | 228.80 | 546.00 | 541.00 | 267.00 | | | |
| Min Peak White | MIN Nominal Peak White | 78.00 | 125.00 | 201.00 | 53.30 | 64.60 | 201.80 | 83.30 | 79.26 | 186.00 | | | |
| AVERAGE "EFFECTIVE GAMMA" using Two HDR->SDR Tone-Mapping Methods (Low Gamma = Midtone Lift) AT/AFTER 2016 | | | | | | | | | | | | | |
| Hybrid-Linear HDR->SDR (Mimics BT.1886 - Linear Scaling) | Average Calculated Hybrid Linear L32 | 2.25 | 2.42 | 2.22 | 2.33 | 2.27 | 2.42 | 2.16 | 1.93 | | | | |
| | MAX Calculated Hybrid-Linear L32 | 2.66 | 2.72 | 2.22 | 2.48 | 2.53 | 2.54 | 2.96 | 2.55 | 0.00 | | | |
| | MN Calculated Hybrid-Linear L32 | 0.33 | 2.20 | 2.22 | 2.13 | 1.72 | 2.29 | 1.14 | 0.84 | 0.00 | | | |
| "Gamma-Adjusted" HDR->SDR (Lifts Shadows and Midtones) | Average Calculated Gamma-Adjusted L32 | 2.00 | 2.08 | 1.95 | 1.94 | 2.11 | 2.11 | 1.86 | 1.75 | 1.33 | | | |
| | MAX Calculated Gamma Adjusted L32 | 2.31 | 2.29 | 1.95 | 1.94 | 2.18 | 2.18 | 2.49 | 2.29 | 1.33 | | | |
| | MN Calculated Gamma-Adjusted L32 | 0.70 | 1.94 | 1.95 | 1.93 | 2.02 | 2.02 | 1.02 | 0.90 | 1.33 | | | |
| Sample Count | Sample Count | 27 | 26 | 2 | 6 | 6 | 3 | 30 | 30 | 2 | | | |
| <u>"Single-Master" Tone Mappings</u> | | | | | | | | | | | | | |
| Hybrid-Linear HDR->SDR (Mimics BT.1886 - Linear Scaling) | Traditional Reference Display Luminance | 100 | Reference Gamma: 2.4 | | | HDR/SDR Unified Reference White Level | 203 | | | | | | |
| "Gamma-Adjusted" HDR->SDR (Lifts Shadows and Midtones) | Rough Gamma Measurement (Identify midtown lift) ≥ 2016 (Additional Picture Modes) | | | | | | | | | | | | |
| "Effective Gamma" Other Picture Modes | Standard | Sports | Vivid | ISF Dark Room | ISF Bright Room | Traditional SDR Reference Displays | 100 | | | | | | |
| | Effective Gamma Hybrid-Linear L32 | 1.95 | 1.79 | 1.92 | 2.33 | 2.05 | Unified Reference White | 203 | | | | | |
| | Effective Gamma Gamma-Adjusted L32 | 1.71 | 1.44 | 1.67 | 2.03 | 1.78 | | | | | | | |
| Calculating for BT.1886 (Gamma 2.4 or Optimal Gain-Staging) Log << MidGray cd/m²>/<>Graphic White cd/m²> / Log <% of signal level of measured gray> = <Rough Gamma Level> | | | | | | | | | | | | | |
| EXAMPLE: $\log(26/203)/\log(0.424658) = 2.4$ | | | | | | | | | | | | | |
| A lower system gamma indicates a lifted gamma (higher shadows and midtones) | | | | | | | | | | | | | |

"Single-Master" Tone Mappings

"Effective-Gamma" Formula

- Legacy SDR Reference White
- LCD Cinema Mode
- FilmMaker LCD
- Factory LCD
- HDR Reference White
- OLED Cinema Mode
- Filmmaker OLED
- Factory OLED



Single-Master HDR-SDR Workflow Recommendations

Reference

| | |
|--|---|
| ITU-R BT.2408 | Guidance for operational practices in HDR television production |
| ITU-R BT.2166 | Viewing conditions for high dynamic range and standard dynamic range monitoring in close proximity within a single-master high dynamic range production environment |
| ITU-R BT.2390 | High Dynamic Range Television For Production and International Programme Exchange |
| EBU R103 | Video Signal Tolerance in digital television system |
| ITU-R BT.2124 | Objective metric for the assessment of the potential visibility of color differences in television |
| ITU-R BT.2100 | Defines the HLG and PQ transfer functions |
| ITU-R BT.2020 | Objective metric for the assessment of the potential visibility of color differences in television |
| ITU-T H Supplement 19 | Summarized list of approximately 47 standards for signaling UHD-HDR-WCG and SDR |
| Color Volume and Hue-Preservation in HDR Tone Mapping | A. Burke, M. D. Smith and M. Zink, in <i>SMPTE Motion Imaging Journal</i> , vol. 129, May 20 th 2020. |

Single-Master HDR-SDR Workflow Recommendations

Acronyms

| | |
|--|--|
| 3D Cube LUT | Efficient R-G-B Tables that allow remapping of both color and light. |
| Tetrahedral Interpolation | Interpolates points in-between values supplied in a LUT using a method that more accurately predicts a correct value based on adjacent LUT values. |
| High Dynamic Range (HDR) | High Dynamic Range – In the context of this discussion HDR represents a larger range of light (from dark to peak white) represented in stops where HLG can represent up to 17 stops and PQ can represent up to 28 stops compared to SDR which can only present up to 5 stops |
| Wide Color Gamut (WCG) | Wide Color Gamut – In the context of this presentation, WCG has a wider range of color represented by the different color primaries defined in ITU-R BT.2020. |
| Stop | 1 stop represents a doubling of light that gets compounded at each additional stop. |
| Display Light Conversion | Uses the source signals display transformation “electro-optical-transfer-function”(EOTF) prior to conversion to another video format (SDR/HLG/PQ). |
| Scene Light Conversion | Converts to a signal that would leave a camera using a specific video format (i.e. HLG, SDR, etc) prior to the conversion to a signal for a display (OETF) |
| Super-Whites | Levels above 100% signal level. Despite the label this also includes colors above 100% signal level. Only some displays will show these levels. |
| Tone-Mapping | Re-mapping of light levels between signals or devices with different dynamic range capabilities. |
| Static Metadata (For PQ HDR) | Defined in ST.2084. Static Metadata defines the mastering displays color volume capabilities. This includes the displays peak brightness, color space and white point. |
| Dynamic Metadata (For PQ HDR) | This includes Dolby Vision, HDR10+, CUVA all of which can define informative tone-mapping metadata on a scene or frame-based basis. |

Single-Master HDR-SDR Workflow Recommendations

Reference Files, Tools and Test Patterns

| | |
|---|--|
| NBCU Single-Master UHD HDR-SDR Workflow and LUTs | Download NBCU LUTs, documentation and test patterns |
| Vooya Video Player | Vooya Video Player Software |
| Color Metric Plug-In for Vooya | Objective Color Metrics plug-in for Vooya Video Player |

Single-Master HDR-SDR Workflow Recommendations

Document History

| Latest Version #: | NBCU-Rec-UHD-HDR-1.23 | | |
|------------------------------|------------------------------|--|--|
| Latest Version Date: | 10/24/25 | | |
| Version # | Date | Revised by | Reason for Change |
| NBCU-Rec-UHD-HDR-1.01 | 03/23/21 | Chris Seeger, Clarence Hau, Michael Drazin, Jim Starzynski | Document Creation and Editing |
| NBCU-Rec-UHD-HDR-1.02 | 04/07/21 | Chris Seeger | Typo and graphics fixes |
| NBCU-Rec-UHD-HDR-1.03 | 4/11/21 | Chris Seeger, Michael Drazin | Replaced degraded graphics, improved Annex 4 |
| NBCU-Rec-UHD-HDR-1.04 | 4/20/21 | Chris Seeger, Michael Drazin | Corrected typos in cross-conversion LUTS (Section 4) |
| NBCU-Rec-UHD-HDR-1.04 | 5/03/21 | Chris Seeger, Mike Zink | <ul style="list-style-type: none"> Updated Section 4 – Added cross-conversion NBCU-LUT7 (HLG to PQ) Added link to ITU-T H Supplement 19 Added link for free MaxRGB Article |
| NBCU-Rec-UHD-HDR-1.04 | 5/11/21 | Chris Seeger | <ul style="list-style-type: none"> Updated Figure 1: “SDR Commercials and Graphics” |
| NBCU-Rec-UHD-HDR-1.05 | 5/21/21 | Chris Seeger | <ul style="list-style-type: none"> Added usage notes for DaVinci Resolve, Adobe, Avid |
| NBCU-Rec-UHD-HDR-1.06 | 06/01/21 | Chris Seeger | <ul style="list-style-type: none"> Added usage notes for Avid and Adobe |
| NBCU-Rec-UHD-HDR-1.07 | 11/01/21 | Chris Seeger | <ul style="list-style-type: none"> Added line-graph examples of ΔE-ITP |
| NBCU-Rec-UHD-HDR-1.08 | 04/10/22 | Chris Seeger | <ul style="list-style-type: none"> Added new Image of production thru distribution |
| NBCU-Rec-UHD-HDR-1.09 | 9/01/22 | Chris Seeger | Changed “Single-Stream” to “Single-Master” |
| NBCU-Rec-UHD-HDR-1.10 | 9/02/22 | Chris Seeger | <ul style="list-style-type: none"> Added link to Adobe Premiere Pro Workflow Document Added updated ITU diagrams |
| NBCU-Rec-UHD-HDR-1.10 | 9/06/22 | Chris Seeger | <ul style="list-style-type: none"> Added description and screenshots for Adobe Premiere and DaVinci Resolve for eDR settings which allow proper display of HDR and SDR on computer desktop displays |
| NBCU-Rec-UHD-HDR-1.12 | 09/23/22 | Chris Seeger | <ul style="list-style-type: none"> Updated description of HLG shading locked to reference white |
| NBCU-Rec-UHD-HDR-1.14 | 03/17/23 | Chris Seeger | <ul style="list-style-type: none"> Add intro text and graphic Reformatted pages Added graphic flow for HDR to SDR |
| NBCU-Rec-UHD-HDR-1.15 | 04/23/23 | Chris Seeger | <ul style="list-style-type: none"> Added TV Luminance Survey to intro and Annex 10 |
| NBCU-Rec-UHD-HDR-1.16 | 07/19/23 | Chris Seeger (note from UHDForum) | Added “Average Luminance” to TV Luminance study plot |
| NBCU-Rec-UHD-HDR-1.17 | 08/14/23 | Chris Seeger | Added section 2.3 for Control Room Display settings with a unified reference white |
| NBCU-Rec-UHD-HDR-1.18 | 01/04/24 | Chris Seeger | Added Table of Contents |
| NBCU-Rec-UHD-HDR-1.19 | 01/05/24 | Chris Seeger | Add section on still image signaling of CICP |
| NBCU-Rec-UHD-HDR-1.19 | 04/11/24 | Chris Seeger | Updated Figure 1 with detail |
| NBCU-Rec-UHD-HDR-1.20 | 10/17/24 | Chris Seeger | <ul style="list-style-type: none"> Updates to initial reference monitor config Replaced Overall workflow drawing |

Single-Master HDR-SDR Workflow Recommendations

| | | | |
|-----------------------|----------|-----------------------------------|--|
| NBCU-Rec-UHD-HDR-1.21 | 12/06/24 | Chris Seeger | Replaced single-master graphic with detail on single-master transmission |
| NBCU-Rec-UHD-HDR-1.22 | 06/23/25 | Chris Seeger | Updated review of document |
| NBCU-Rec-UHD-HDR-1.23 | 10/24/25 | Chris Seeger (note from UHDForum) | <ul style="list-style-type: none">Added ITU-R BT.2166 info: Viewing conditions for high dynamic range and standard dynamic range monitoring in close proximity within a single-master high dynamic range production environmentReplaced duplicated drawings from BT-2408 and instead provided links to the up-to-date documents |