greenMachine®

HDR™ Static

Static HDR Processing for greenMachine titan

Revision 3.1 – May 2020

LYNXTechnik AG®

Broadcast Television Equipment

THIS MANUAL SUPPORTS:	
titan from Revision	862
greenGUI from Revision	2.11.0

Contents

1. Overview

The greenMachine HDR STATIC Constellation is a fully-featured broadcast-quality HDR-to-SDR, SDR-to-HDR, or cross-standard HDR-to-HDR converter, with frame sync and up/down/cross-converters supporting formats up to 4K UHD (3840x2160). The HDR STATIC Constellation applies color and contrast parameters equally throughout a specific piece of content, i.e. an average brightness/color range is determined across an entire program.

The HDR STATIC Constellation is part of a suite of constellations that can be deployed on the greenMachine titan 4-channel hardware platform. It provides either a single 12G 4K-UHD processing channel or four independent processing channels for SDI signals up to 1080p 3Gbit/s.

With High Dynamic Range (HDR) there are completely new possibilities for broadcast and AV productions to provide an increased dynamic range for the viewer, including brighter highlights and more details in dark areas resulting in more brilliant and realistic images. This is because modern image sensors offer significantly wider dynamic color ranges. But classic Standard Dynamic Range (SDR) TV devices are only able to reproduce the older dynamic range of SDTV and HDTV standards but not the extended dynamic range of HDR. One of the major challenges when introducing HDR with its tremendous image enhancements is to maintain good backward compatibility with existing SDR displays and receivers.

The greenMachine HDR-STATIC Constellation is a powerful tool for handling dynamic ranges and color gamuts offering viewers more dynamic images than previously seen, even without an up-to-date HDR display. It provides conversion functionality, simultaneously combining it with a static (real-time) tone mapping algorithm. This application allows the user to carry out up-, down- and cross-conversions between common transfer characteristics including Gamma BT.709, PQ, HLG, SLog3, and other proprietary camera capture curves of common camera manufacturers using the appropriate static tone mapping. The HDR STATIC application is also capable of performing conversions between color spaces including Rec. 601, Rec. 709, Rec. 2020, DCI-P3, ACES, and the respective proprietary color spaces of the common manufacturers corresponding to their capture curves as well as conversions between full and (100% and 109%) narrow range signals. This allows HDR content to be displayed on non-HDR-capable TV-monitors by using contrast compression, producing a high level of HDR-enhanced image quality for any type of display device.

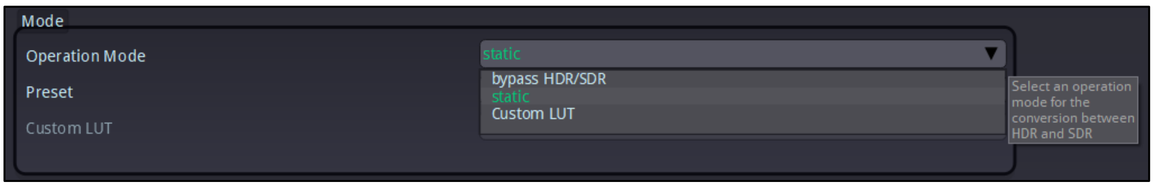
This greenMachine HDR STATIC Constellation also includes spatial up-, down- and cross-conversions up to 4K UHD, audio processing and shuffling, color correction, timing adjustment, Meta Data processing and the Nova controller which enables the greenMachine to be remotely controlled and monitored via third party master control software.

CustomControl is also included providing simplified customized screen panels offering direct access to user-selected parameters.

This document describes the HDR processing part of the HDR-STATIC Constellation.

2. Operation Modes

The HDR processor provides three user-selectable modes: “bypass HDR/SDR”, “static” and “Custom LUT”.



Selecting an Operation Mode

2.1. Operation Mode “bypass HDR/SDR”

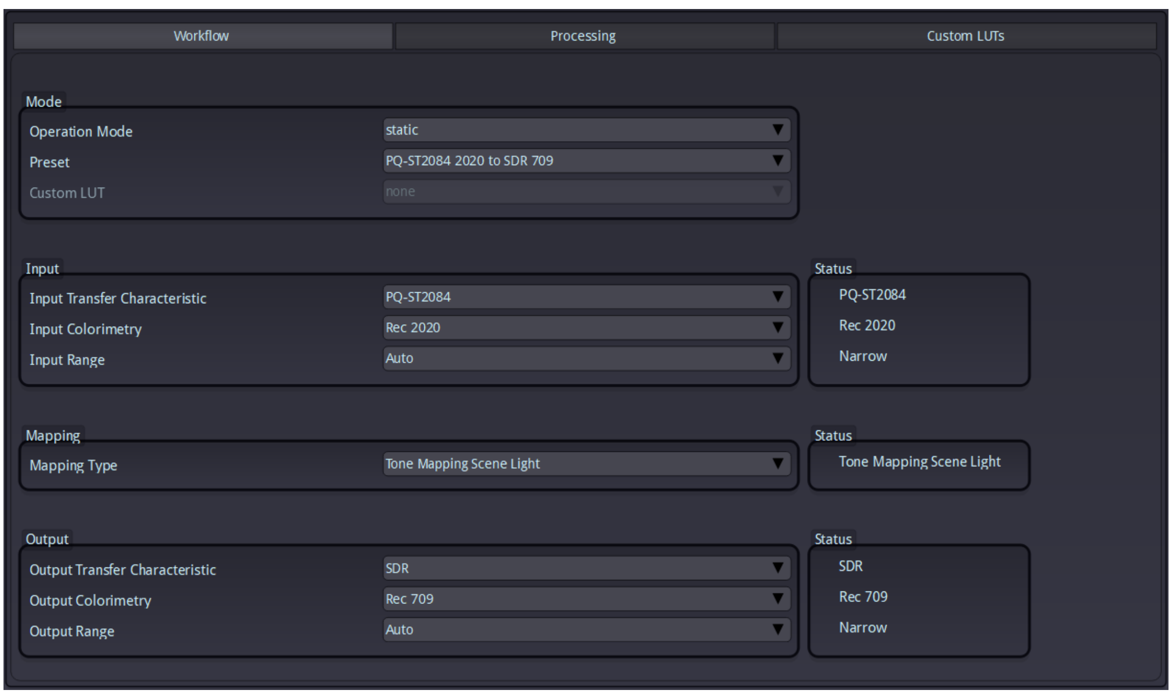
The “bypass HDR/SDR” mode bypasses the HDR conversion functionality of “Transfer Characteristics”, “Colorimetry” (color spaces) and “Ranges” (between narrow and full range) in connection with HDR transfer characteristics, i.e. no HDR-to-SDR down-conversion, SDR-to-HDR up-conversion or cross-conversion between HDR characteristics will be performed. The incoming transfer characteristic of the signal is transparently passed through the system. Conversions of “Colorimetry” and “Ranges” in connection with HDR characteristics will not be performed either. In this mode, only “Colorimetry” and “Range” conversions of SDR (Gamma BT.709) signals are performed correctly, because the conversion functionality for “Colorimetry” and “Range” conversions of SDR signals is also available independently of the HDR STATIC Constellation in the greenMachine and thus remains untouched upon activation of “bypass HDR/SDR”. Therefore, these types of conversions continue to be performed, so attention should be paid to the selected input/output “Colorimetry” and “Range” as these conversions are only performed correctly in connection with SDR (Gamma BT.709) signals. When it comes to performing these conversions in connection with HDR signals, the Operation Mode “static” must be selected. Besides the ability to bypass input signals, the Operation Mode “bypass HDR/SDR” can also be used to check on input signals and to illustrate the effect of mapping the present input signal or converting the transfer characteristic of this signal.

2.2. Operation Mode “static”

The Operation Mode “static” activates the actual operation mode of the HDR STATIC Constellation, in which SDR *and* HDR signals can be processed and conversions in connection with these HDR signals can be performed. Depending on the use case, this mode combines two main functions, HDR conversions between transfer characteristics and mappings, which are explained in more detail below.

2.2.1. HDR Conversions

The Operation Mode “static” allows the user to perform conversions between different transfer characteristics (e.g. “PQ-ST2084” and “SDR” [Gamma BT.709] as shown in the figure below). Conversions of transfer characteristics from HDR to SDR (e.g. “PQ-ST2084” to “SDR” [Gamma BT.709]) are referred to as “HDR-to-SDR down-conversion”, conversions from SDR to HDR (e.g. “SDR” [Gamma BT.709] to HLG) as “SDR-to-HDR up-conversions”. Conversion between an HDR characteristic and another HDR characteristic is called “HDR cross-conversion”. The exact meanings of these conversions, as well as the characteristics they contain, are discussed in more detail in their respective chapters. To perform these conversions several “Mapping Types” are available, which are described in the following chapter.



Available Conversions

Note: *In the HDR STATIC Constellation it is also possible to perform conversions of Colorimetry (color spaces) and signal ranges (between narrow and full). However, the conversion functionality for Colorimetry and Range conversions of SDR signals is also available in the greenMachine independently of the HDR STATIC Constellation (see. 2.1. “Operation Mode “bypass HDR/SDR”).*

2.2.2.Mapping

Especially conversions such as down- and up-conversions require a mapping of the luminance values in order to convert an image from the HDR format into the SDR format or vice versa. Different methods, so-called “Mapping Types”, are available in the HDR STATIC Constellation to perform such conversions.

Direct Mapping

The simplest type of mapping is the Direct Mapping since changes in luminance are only made proportionally with a slight gain. This gain is applied in order to keep the appearance between SDR and HDR white levels about the same.

Therefore, in the case of SDR-to-HDR up-conversion, a direct mapping according to ITU Report BT.2408 preserves the appearance of the SDR content and makes the up-converted HDR version displayed on an HDR monitor almost look identical to the original SDR version displayed on an SDR monitor. Nevertheless, the result can be a bit dark and may need to be manually adjusted by processing* in order to get better mixed with material from HDR cameras. In the case of up-conversion, Direct Mapping can be used, especially for up-converting graphics but also for normal image content.

Note: *The use of the Gain parameter can help this (see chapter 2.2.3. “Processing Parameters”).*

In the opposite case of HDR-to-SDR down-conversion, according to BT.2408, Direct Mapping is also “useful when the signal from an HDR camera is required to look similar to the signal delivered by an SDR camera operated without a ‘knee’”, which is sometimes used in conventional video cameras in order to exploit their full dynamic range and thus to extend the dynamic range of the signal. However, in this case of down-conversion, this also means that (high-)lights above the SDR format are simply cut off, which leads to severe clipping of highlights in the down-converted SDR image. As a result, the picture will be burnt out in bright areas. Thus, the converted SDR does not benefit from the increased capture quality of HDR due to the high loss in lights and shadows. Therefore, this procedure is only suitable for scenes with a lower contrast range in this case of down-conversion or for the already mentioned use case according to BT.2408 to match HDR cameras with SDR cameras. However, this approach is well predictable and leads to a steep image impression.

The Direct Mapping operation of the HDR STATIC Constellation (when set to default [Gain = 0 dB], see chapter 2.2.3. “Processing Parameters”) follows the recommendations of BT.2408 as shown in the first table at the end of this chapter. This table gives information on which luminance 100% ‘SDR reference white’ will be mapped onto an HDR reference monitor with 1000 cd/m² in case of up-conversion (see the left side in blue) and which luminance displayed on an HDR reference monitor with 1000 cd/m² will be mapped to 100% 'SDR reference white' in case of down-conversion (see the right side in green). As shown in the table, these values are fairly accurate to the HDR level guidance provided in ITU Report BT.2408 (203 cd/m² reference level). Thus, it is ensured that SDR and HDR content has a similar level for HDR reference white. Moreover, the table at the end of this chapter contains the scene luminance (i.e. with inverted OOTF) corresponding to the respective display luminance already mentioned. An example of how to read and understand the table can be found at the end of this chapter as well as in chapter 2.2.3. "Processing Parameters". In addition, these luminance values resulting from the Direct Mapping operation are displayed in the GUI under the "Processing" tab depending on the selected gain (see chapter 2.2.3. "Processing Parameters"). This allows monitoring to which luminance the 100% 'SDR reference white' is mapped in HDR in case of up-conversion or which luminance in HDR is mapped to 100% 'SDR reference white' in case of down-conversion.

Furthermore, the Direct Mapping operation is also roundtrip capable in the sense of BT.2408. This means that the image impression remains unchanged after "round-tripping" from SDR to HDR and back again to SDR, which is also illustrated in the example from chapter 2.2.3. "Processing Parameters".

For more information on Direct Mapping and its use within production workflows, see ITU Report BT.2408, where the suggested format conversions and the resulting looks for PQ and HLG production are described in detail.

Tone Mapping

Since a simple conversion with a slight adjustment of the luminance is usually not sufficient, there is another mapping type called "Tone Mapping" provided in the Operation Mode "static". This type of mapping applies a real-time static tone mapping, which automatically adjusts the signal to the new target format selected. Technically, the brightness and color information outside the target format is changed in a way that it is not much clipped and fits into the new target format.

In the case of down-conversion, the high dynamic range of image content is compressed to the smaller standard dynamic range; in the case of up-conversion, the smaller standard dynamic range is expanded to the higher dynamic range. During the respective conversion, the brightness component is adjusted, and colors are treated accordingly. This makes it possible to preserve (high-)lights in case of HDR-to-SDR down-conversion. The result: Clipping of the (high-)lights caused by a down-conversion is mostly prevented and up-converted signals appear more brilliant overall and get a different impression of depth. In principle, Tone Mapping is better suited for up- and down-conversions than Direct Mapping, especially for mapping cameras, since the Tone Mapping operation creates a stronger HDR look in case of up-conversion and is also able to preserve more contrast in case of down-conversion.

The Operation Mode in which the Tone Mapping is executed is called “static” because the adjustment of the signal is carried out via a static curve similar to a knee function, which is sometimes used within conventional video cameras in order to exploit their full dynamic range and thus to extend the dynamic range of the signal. The advantage of using a static curve is that it always behaves the same way. By that, the result is continuous and also best predictable. Furthermore, this Mapping Type also provides correct “round-tripping” ability since the exact inverse function for the applied static tone mapping function is used for backward conversion.

In ITU Report BT.2408 this type of mapping is referred to as “down-mapping” (or tone mapping) in case of HDR-to-SDR down-conversion and “up-mapping” (or inverse tone mapping) in case of SDR-to-HDR up-conversion. According to BT.2408, down-mapping for downstream mixing with SDR cameras or converting the complete programme output “is preferred to allow the SDR signal to benefit from the HDR production workflow”. Furthermore, in case of up-conversion, “up-mapping (which expands highlights in the SDR signal) is preferred to ensure a closer match between HDR and SDR cameras”. In addition, up-mapping can also be used elsewhere in a (live) production workflow, e.g. to insert graded SDR content into a production programme. For more information on static tone mapping and its use within production workflows, see ITU Report BT.2408, where the suggested format conversions and the resulting looks for PQ and HLG production are described in detail.

The second table at the end of this chapter contains the same information regarding the Tone Mapping operation as the first table provides for Direct Mapping operation. It illustrates on which luminance 100% ‘SDR reference white’ will be mapped onto an HDR reference monitor with 1000 cd/m² in case of up-conversion (see the left side in blue) and which luminance displayed on an HDR reference monitor with 1000 cd/m² will be mapped to 100% ‘SDR reference white’ in case of down-conversion (see the right side in green). Furthermore, this table contains the scene luminance (i.e. with inverted OOTF) corresponding to the respective display luminance as well. An example of how to read and understand the table can be found at the end of this chapter as well as in chapter 2.2.3. “Processing Parameters”.

Note: A cross-conversion only supports Direct Mapping, since there is no need for a brightness correction by a tone mapping operation in this case. If Tone Mapping Scene Light or Tone Mapping Display Light is selected in the case of cross-conversion, the Mapping Type will be forced to the respective Direct Mapping Type.

In addition, these luminance values resulting from the Tone Mapping operation are also displayed in the GUI under the “Processing” tab depending on the selected gain (see chapter 2.2.3. “Processing Parameters”). This allows monitoring to which luminance the 100% ‘SDR reference white’ is mapped in HDR in case of up-conversion or which luminance in HDR is mapped to 100% ‘SDR reference white’ in case of down-conversion.

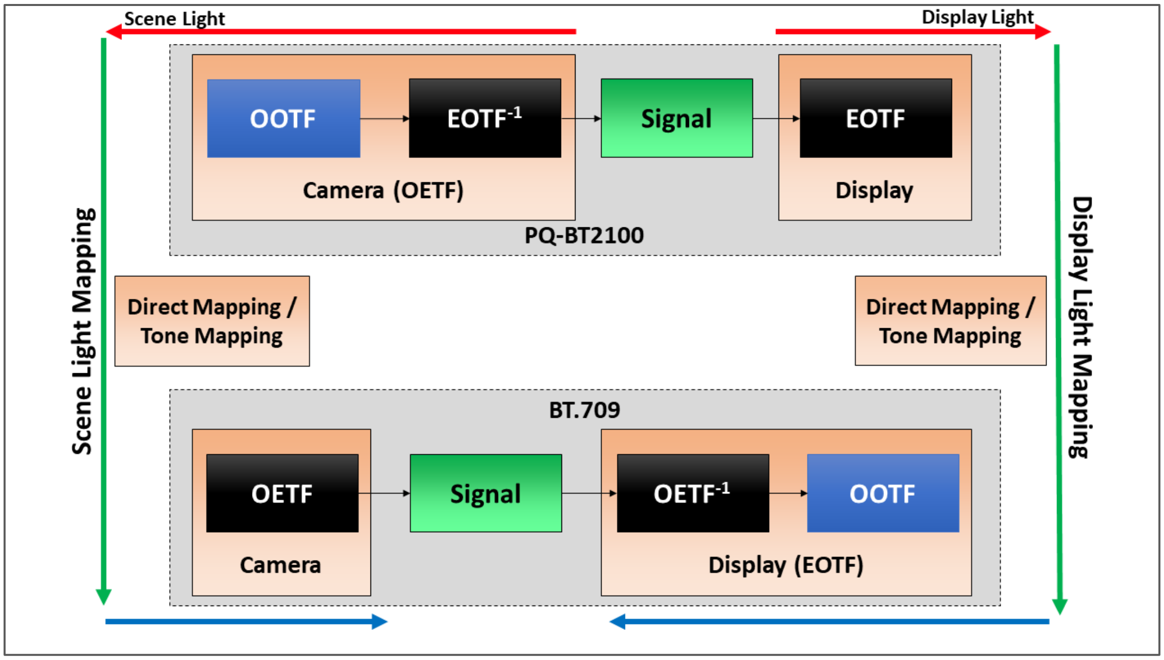
Scene Light or Display Light Mapping

Both Mapping Types, Direct Mapping and Tone Mapping, can each be executed with two possible approaches depending on two different use cases. Either with the scene-referred Mapping Type (Scene Light Mapping) or with the display-referred Mapping Type (Display Light Mapping).

According to ITU Report BT.2390 and BT.2408, the “display-referred mapping is used when the goal is to preserve the colours and relative tones seen on an SDR display when the content is shown on an HDR display. An example of this is the inclusion of SDR graded content within an HDR programme. Display-referred mappings are derived by scaling the light reproduced by a reference display”.

Whereas the “scene-referred mapping is used when the goal is to match the colours and relative tones of an HDR and SDR camera; an example of which is the inter-mixing of SDR and HDR cameras within a live television production. Scene-referred mappings are based on the light falling on the camera sensor, but they include any camera characteristics, white balance, and any artistic camera adjustments”.

In other words, by using Scene Light Mapping, the incoming signal is first used to reconstruct the brightness levels of the scene before the selected mapping operation is performed. This process is explained in more detail using the example of a down-conversion from PQ-BT2100 to SDR (Gamma BT.709) as shown in the figure on the following page. In this case, the incoming signal at the input of the HDR processor, e.g. directly derived from the output of a camera operating in PQ-BT2100, corresponds to the upper green “Signal” block in the figure. As shown by the upper red arrows and by the order of the camera and display blocks, the left side of the figure represents scene light, while the right side of the figure represents the light output of the display (display light). In order to reconstruct the original linear scene light, the non-linear process that took place within the camera during image capture with PQ-BT2100 (OOTF + $EOTF^{-1}$) must be undone (see the red arrow at top left). Therefore, the EOTF of PQ-BT2100 is applied first in order to undo the inverse EOTF ($EOTF^{-1}$), whereupon the inverse OOTF ($OOTF^{-1}$) of PQ-BT2100 is applied in order to undo the OOTF. Once the original scene light has been reconstructed, the actual mapping operation will be performed with either Direct Mapping



Scene Light vs Display Light Mapping using the example of down-conversion from PQ-BT2100 to SDR (Gamma BT.709)

(Scene Light) or Tone Mapping (Scene Light) in order to carry out the HDR-to-SDR down-conversion (see left green arrow). Since the down-converted scene light is still linear, the non-linear processing of an SDR camera, according to the OETF specified in BT.709, has to be simulated in the last step (see blue arrow bottom left) to get the final SDR signal (bottom green "Signal" block). After applying the reference BT.709 OETF, the final SDR signal is available for display on an SDR display. The whole process can also be performed in the reverse arrow direction in case of an up-conversion.

By using Display Light Mapping, it is not the brightness values of the scene that are used as a reference for the mapping, but the brightness levels which the input signal would cause on a reference monitor. This process can be explained in detail by taking a closer look at the right side of the down-conversion example from PQ-BT2100 to SDR (Gamma BT.709) shown in the figure above. As in the previous case of Scene Light Mapping, the incoming signal at the input of the HDR processor also corresponds to the upper green "Signal" block in the figure. In order to derive the display light, which is caused by this signal on a PQ reference monitor, the EOTF of PQ is applied to the signal (see the red arrow at top right), according to the reproduction of such a monitor. Once the display light has been derived, the actual mapping operation will be performed with either Direct Mapping (Display Light) or Tone Mapping (Display Light) in order to carry out the HDR-to-SDR down-conversion (see the right green arrow). Now the down-converted SDR display light must be transferred into a signal that can be displayed on an SDR monitor using the BT.1886 EOTF (BT.709 OETF^{-1} + OOTF). For this purpose, exactly the inverse of this EOTF is applied to the signal (see blue arrow bottom right), i.e. the signal is first passed through the inverse BT.709/BT.1886 OOTF

($OOTF^{-1}$) before the BT.709 OETF will be applied. Once these steps are done, the final SDR signal (bottom green "Signal" block) is available and can be displayed on an SDR monitor. Therefore, Display Light Mapping should be used in order to view HDR content on displays with a lower dynamic range. The whole process can also be performed in the reverse arrow direction in case of an up-conversion.

It is particularly important that Scene Light Mapping is used for matching SDR and HDR camera signals since both signals represent light from the scene captured by the camera. If Display Light Mapping would be used, SDR and HDR cameras (especially HLG camera signals) would not match, because the displayed look of SDR and HDR images is different due to the difference in the opto-optical transfer functions (OOTFs). Therefore, the difference between scene light and display light is the OOTF, which is described in more detail in chapter 3. "Transfer Characteristic" together with subjects like OETF and EOTF.

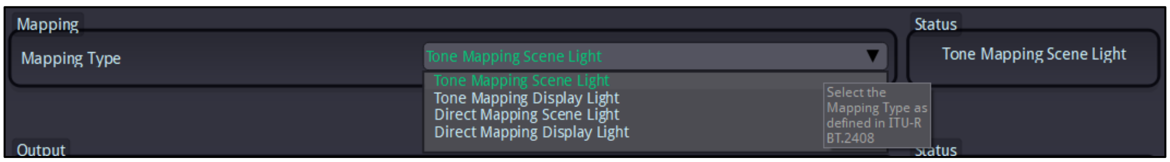
While Display Light Mapping tends to preserve the look created by the transfer characteristic used by the display (plus artistic intent), Scene Light Mapping tends to represent the look of the signal being converted to. In this case of HDR-to-SDR down-conversion from PQ-BT2100 to SDR (Gamma BT.709), Display Light Mapping would, therefore, lead to a PQ look, while Scene Light Mapping would result in a "traditional" BT.709 look. However, in the latter case, the resulting look depends on which system the shading takes place (HDR or SDR) and whether artistic intents have already been included during capturing process. In the opposite case of SDR-to-HDR up-conversion from SDR (Gamma BT.709) to PQ-BT2100, Display Light Mapping would result in the "traditional" BT.709 look, while Scene Light Mapping would lead to a PQ look.

According to BT.2408, e.g. the primary HDR output of a production switcher, which for distribution must be converted into SDR, should be derived via Display Light Mapping to ensure that both the SDR and HDR signals have the same look. Another example would be the conversion of SDR graphics into HDR. According to BT.2408, "a scene-light mapping is usually preferred where the desire is to match signage within the captured scene (in-vision signage; e.g. a score board at a sporting event)", whereas "a display-light mapping should be used where the desire is to maintain the colour branding of the SDR graphics", "as that should ensure the same hue and saturation of graphics in both HDR and SDR".

It should also be noted that after "round-tripping" (SDR>HDR>SDR) within a production using Display Light Mapping for up-conversion and Scene Light Mapping for down-conversion, any SDR material (e.g. graded inserts or graphics) will show a difference in saturation at the end of the signal chain compared to the original SDR version. The result will appear more saturated than intended in the case of HLG production or slightly less saturated than intended for PQ production. For this reason, scene light and display light conversion in combination should be used with care and multiple conversions of such kind should be avoided.

For more information on scene light and display light mapping and its use within production workflows, see ITU Report BT.2408, where the suggested format conversions and the resulting looks for PQ and HLG production are described in detail. For more detailed technical descriptions on how Scene Light and Display Light Mapping is being processed, see ITU Report BT.2390.

The following illustration shows the possible selection of the four Mapping Type combinations “Tone Mapping Scene Light, “Tone Mapping Display Light”, “Direct Mapping Scene Light” and “Direct Mapping Display Light” available in the HDR STATIC Constellation.



Selecting a Mapping Type

As already explained in the subchapters “Direct Mapping” and “Tone Mapping” at the beginning of this chapter, the following tables give information on which luminance 100% ‘SDR reference white’ will be mapped onto an HDR reference monitor with 1000 cd/m² in case of up-conversion (see the left side in blue) and which luminance displayed on an HDR reference monitor with 1000 cd/m² will be mapped to 100% ‘SDR reference white’ in case of down-conversion (see the right side in green) using Direct Mapping or Tone Mapping. Furthermore, the tables contain the scene luminance (i.e. with inverted OOTF) corresponding to the respective display luminance. In addition, these luminance values resulting from the selected mapping operation are also displayed in the GUI under the “Processing” tab depending on the selected gain (see chapter 2.2.3. “Processing Parameters”). This allows monitoring to which luminance the 100% ‘SDR reference white’ is mapped in HDR in case of up-conversion or which luminance in HDR is mapped to 100% ‘SDR reference white’ in case of down-conversion. If Scene Light Mapping is selected, the respective HDR scene luminance is displayed, if Display Light Mapping is selected, the respective HDR display luminance is displayed (see chapter 2.2.3. “Processing Parameters”).

Examples of how to read and understand the tables are given below.

Note:

1) *Conversions including PQ-ST2084 and proprietary transfer characteristics such as SLog3 by Sony, Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2 and BMD Film only support Scene Light Mapping. If Tone Mapping Display Light or Direct Mapping Display Light is selected in case of conversion with these characteristics, the Mapping Type will be forced to the respective Scene Light Mapping Type.*

An overview of the existing limitations regarding Mapping Types and Transfer Characteristics is given in the tables of the appendix at the end of the document. The chapter also contains all the other restrictions that apply in the HDR STATIC Constellation.

	up-conversion			down-conversion		
Direct Mapping	Scene Light					
	Gain [dB]	max. cd/m² (on display)*	max. cd/m² (at scene)**	Gain [dB]	max. cd/m² (on display)***	max. cd/m² (at scene)****
	-12	40	79	-12	1010	1259
	-6	93	159	-6	463	631
	0	209	316	0	209	316
	+6	463	631	+6	93	159
	+12	1010	1259	+12	40	79
	Display Light					
	Gain [dB]	max. cd/m² (on display)*	max. cd/m² (at scene)**	Gain [dB]	max. cd/m² (on display)***	max. cd/m² (at scene)****
	-12	50	99	-12	794	992
	-6	100	176	-6	398	557
	0	200	314	0	200	314
	+6	398	557	+6	100	176
	+12	794	992	+12	50	99

* luminance [in cd/m²] on an HDR reference monitor with 1000 cd/m² (table without clipping)
** luminance [in cd/m²] in the scene (inverting the OOTF)
*** luminance [in cd/m²] on an HDR reference monitor with 1000 cd/m² which will be mapped to 100% SDR reference white
**** luminance [in cd/m²] in the scene (inverting the OOTF) which will be mapped to 100% SDR reference white

Example with the following assumption:

In the case of "round-tripping" an SDR signal (SDR>HDR>SDR), the Mapping Type "Direct Mapping Display Light" with default settings (Gain = 0 dB) is used. During up-conversion (see the left side in blue), the 100% 'SDR reference white' of this signal will be mapped to be displayed with 200 cd/m² on an HDR reference monitor with 1000 cd/m² peak luminance. The scene luminance corresponding to this display luminance is 314 cd/m². When down-converting this signal back to SDR (see the right side in green), the exact value of 200 cd/m² displayed on the HDR reference monitor with 1000 cd/m² peak luminance will be mapped back to the level of the initial 100% 'SDR reference white'.

The same applies to the next example with “Tone Mapping Scene Light”.

	up-conversion			down-conversion		
Tone Mapping	Scene Light					
	Gain [dB]	max. cd/m² (on display)*	max. cd/m² (at scene)**	Gain [dB]	max. cd/m² (on display)***	max. cd/m² (at scene)****
	-12	56	104	-12	1371	1654
	-6	129	208	-6	631	829
	0	287	415	0	287	415
	+6	631	829	+6	129	208
	+12	1371	1654	+12	56	104
	Display Light					
	Gain [dB]	max. cd/m² (on display)*	max. cd/m² (at scene)**	Gain [dB]	max. cd/m² (on display)***	max. cd/m² (at scene)****
	-12	70	131	-12	1106	1306
	-6	139	232	-6	554	734
	0	278	413	0	278	413
	+6	554	734	+6	139	232
	+12	1106	1306	+12	70	131

* luminance [in cd/m²] on an HDR reference monitor with 1000 cd/m² (table without clipping)
** luminance [in cd/m²] in the scene (inverting the OOTF)
*** luminance [in cd/m²] on an HDR reference monitor with 1000 cd/m² which will be mapped to 100% SDR reference white
**** luminance [in cd/m²] in the scene (inverting the OOTF) which will be mapped to 100% SDR reference white

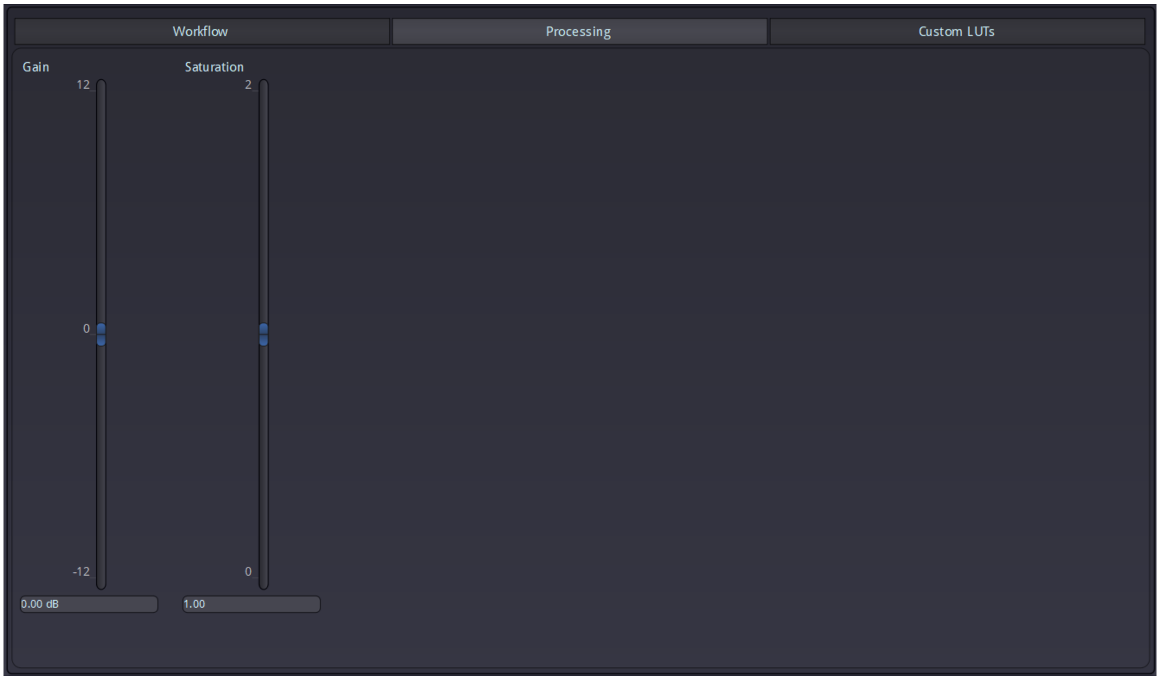
Example with the following assumption:

In the case of “round-tripping” an SDR signal (SDR>HDR>SDR), the Mapping Type “Tone Mapping Scene Light” with default settings (Gain = 0 dB) is used. During up-conversion (see the left side in blue), the 100% ‘SDR reference white’ of this signal will be mapped to be displayed with 287 cd/m² on an HDR reference monitor with 1000 cd/m² peak luminance. The scene luminance corresponding to this display luminance is 415 cd/m². When down-converting this signal back to SDR (see the right side in green), the exact value of 287 cd/m² displayed on the HDR reference monitor with 1000 cd/m² peak luminance will be mapped back to the level of the initial 100% ‘SDR reference white’.

Further examples can be found in the following chapter.

2.2.3. Processing Parameters

The following processing parameters can be adjusted manually in the Operation Mode "static".



Available Processing Parameters

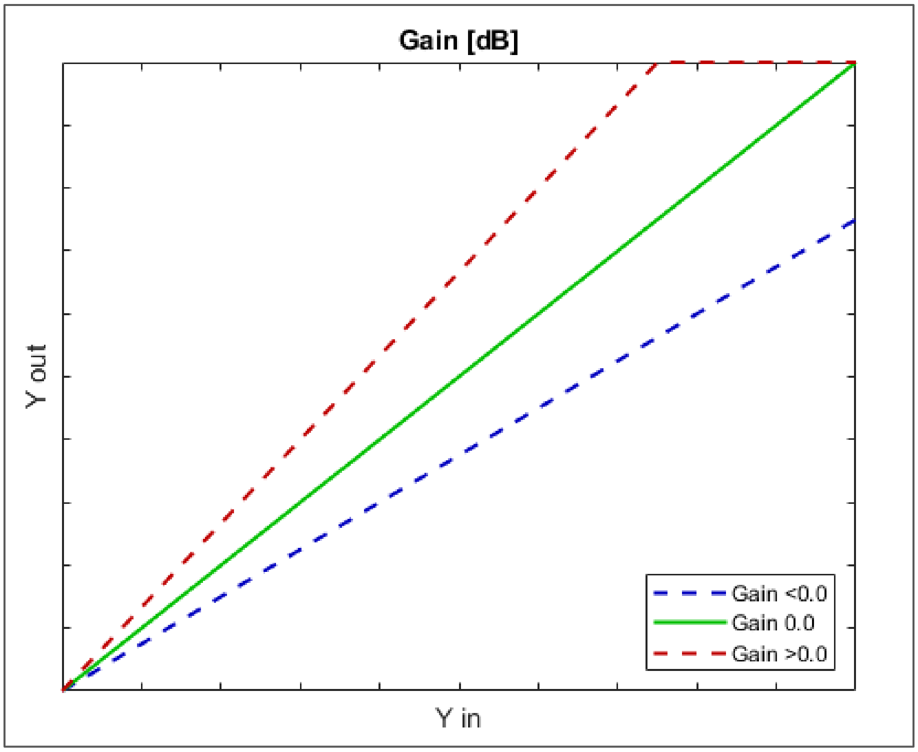
Gain [dB]

This parameter can be used to adjust the luminance of the overall image. Basically, it changes the slope or lift of the luminance level. The default value is set to 0.00 dB and leaves the image unchanged, whilst a value less than 0.00 dB reduces the brightness and a value greater than 0.00 dB increases the brightness of the image.

+12,00 dB: extremely increased brightness
+0.00 dB: unchanged
-12,00 dB: extremely decreased brightness

The figure on the following page illustrates the effect of the parameter on the luminance level of the image. As you can see in the graphic, an increased gain can lead to clipping of the lights for high luminance values at the input, as shown in the red dashed curve.

If the image appears too dark, e.g. after an SDR-to-HDR up-conversion, a luminance gain can be used to adjust the image and achieve better matching to the luminance of native HDR material. This processing can be undone in case of "round-tripping" if the inverse value is used for the reverse conversion. For example, if the value +3.0 dB was selected

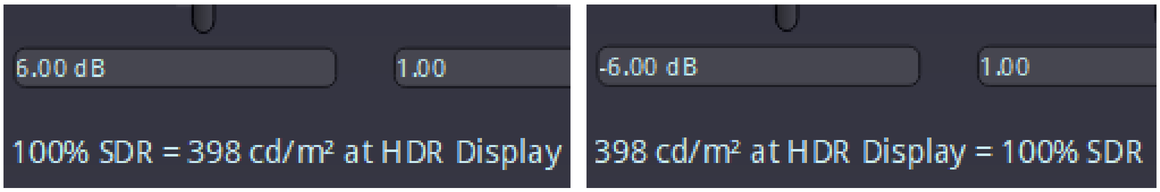


The behavior of the Gain parameter

during the first conversion from SDR to HDR, the value -3.0 dB must be selected during reconversion back from HDR to SDR. A more detailed example is given in the following, based on the tables at the end of the previous chapter (see 2.2.2. “Mapping”).

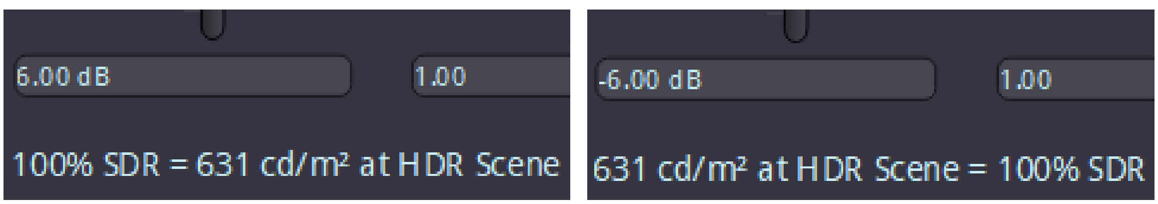
Example with the following assumption:
In the case of “round-tripping” an SDR signal (SDR>HDR>SDR) using the Mapping Type “Direct Mapping Display Light”, a gain of +6.0 dB is used during up-conversion, since the HDR result without adjusting the gain would appear too dark compared to native HDR content. In this case, the 100% ‘SDR reference white’ of this signal will be mapped to be displayed with 398 cd/m² on an HDR reference monitor with 1000 cd/m² peak luminance (see left blue side of the first table in chapter 2.2.2. “Mapping”). The scene luminance corresponding to this display luminance is 557 cd/m². When down-converting this signal back to SDR, the gain parameter must be set to -6.0 dB in order to map back the exact value of 398 cd/m² displayed on the HDR reference monitor with 1000 cd/m² peak luminance to the level of the initial 100% ‘SDR reference white’ (see the right green side of the first table in chapter 2.2.2. “Mapping”).

As already mentioned in chapter 2.2.2. “Mapping” and shown in the following figure, these luminance values resulting from the selected mapping operation are additionally displayed in the GUI under the “Processing” tab depending on the selected gain (see chapter 2.2.3. “Processing Parameters”). The luminance value resulting at the HDR display by using Direct Mapping Display Light with a 6.0 dB gain for up-conversion is shown in the left figure and the luminance value at the HDR display which will be mapped to 100% ‘SDR reference white’ by using Direct Mapping Display Light with a -6,0 dB gain for the subsequent down-conversion is shown in the right figure. This allows easy monitoring of the resulting or used luminance values of the respective mapping operations.



Luminance values resulting from Direct Mapping Display Light using a 6.0 dB gain for up-conversion (left) and a -6.0 dB gain for the subsequent down-conversion (right)

If Scene Light Mapping is selected, instead of displaying the HDR display luminance the corresponding HDR scene luminance, which results in case of up-conversion or will be mapped to 100% ‘SDR reference white’ in case of down-conversion is displayed as shown in the following figure. The tables at the end of chapter 2.2.2. “Mapping” offers an overview of the correlation between the luminance values of scene light and display light.



Luminance values resulting from Direct Mapping Scene Light using a 6.0 dB gain for up-conversion (left) and a -6.0 dB gain for the subsequent down-conversion (right)

The luminance values are also displayed in the GUI when using Tone Mapping Scene Light or Tone Mapping Display Light.

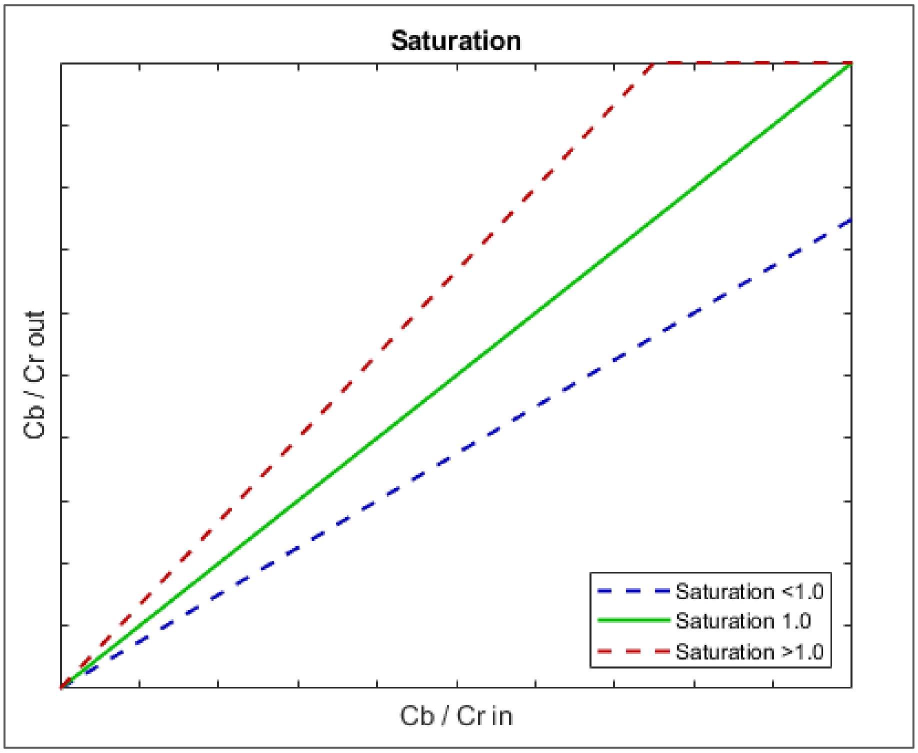
Saturation

Due to the performed contrast conversion as well as a possible adjustment of the gain parameter, which also influences the performed conversion, an adjustment of the brightness component is performed, which in turn affects the color impression such as the saturation. Due to these changes, the chrominance is generally treated accordingly. If the saturation impression still does not match the expectations, the "Saturation" parameter offers the possibility to adjust it.

Basically, this parameter changes the slope or lift of the color saturation. The default value is set to 1.0 and leaves the saturation unchanged, whilst a value less than 1.0 reduces the saturation and a value greater than 1.0 increases the saturation (see figure on the following page).

2.0: extremely increased saturation
1.0: saturation unchanged
0.0: extremely reduced saturation

However, an increase in saturation can lead to color clipping for already highly saturated colors at the input, as shown in the red dashed curve of the following figure.



The behavior of the Saturation parameter

This processing can be undone in case of “round-tripping” if the inverse value is used for the reverse conversion. For example, if the value 1.2 was selected during the first conversion from SDR to HDR, the value 1/1.2 ≈ 0.83 must be selected during reconversion back from HDR to SDR.

The following table shows which settings of the individual processing parameters are considered meaningful and which are critical. The default value is marked with a cross. Extreme areas that carry an increased risk of undesired behavior are marked in red.

		-12	-9	-6	-3	0	+3	+6	+9	+12	
Gain [dB]						X					
	0,0	0,2	0,4	0,6	0,8	1,0	1,2	1,4	1,6	1,8	2,0
Saturation						X					

Overview of meaningful (green) and critical (red) settings of the processing parameters

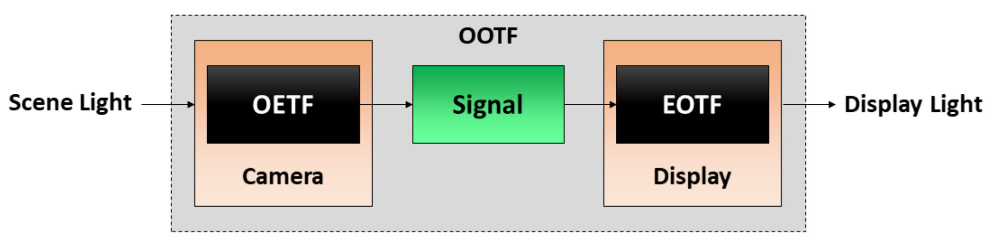
2.3. Operation Mode "Custom LUT"

The Operation Mode "Custom LUT" allows users to select their own LUTs to obtain the desired contrast, color, saturation, black and white levels. Users are provided with 20 slots to upload up to 20 custom LUTs. At a time, one processing channel can apply one custom LUT. Each custom LUT is configured with the input and output Transfer characteristics, Colorimetry and Range.

3. Transfer Characteristics

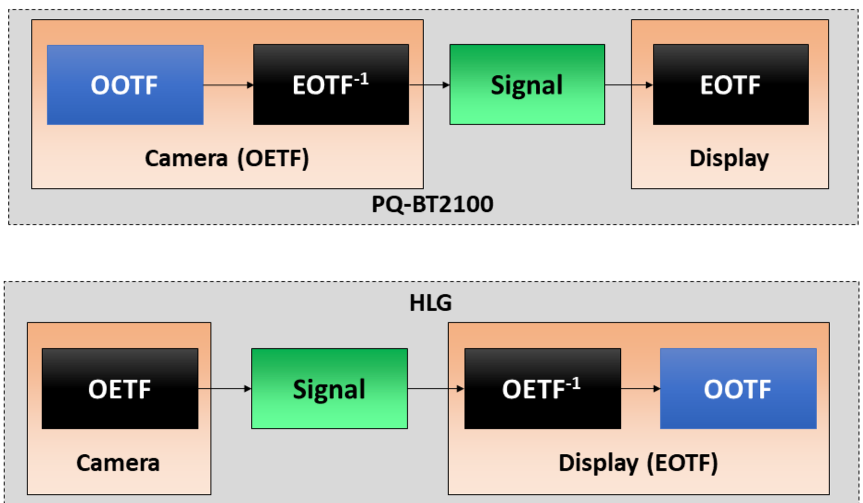
The conversion between different transfer characteristics is considered the main function of the HDR processor, since the actual HDR-to-SDR and SDR-to-HDR conversions take place at this point. The operation of direct mapping or static tone mapping is carried out at this point as well. In order to use these features, the Operation Mode "static" must be selected (see chapter 2. "Operation Modes").

Basically, a transfer characteristic can be described as follows: On the recording side typically within a camera, an opto-electronic transfer function (OETF) is responsible for the transfer of optical brightness information (scene light) into the electrical (digital) video signal (see figure below). Thus, the transfer characteristic of the resulting video signal corresponds to the OETF in use. On the display side, the electro-optical transfer function (EOTF) ensures the transfer of the electrical (digital) video signal back into optical brightness information (display light) as shown in the following figure.



Relationship between OETF, EOTF and OOTF

So, the OETF maps the light coming from the scene to the video signal and the EOTF maps the signal representing the scene to the light emitted from the display. The OETF and EOTF in combination result in the opto-optical transfer function (OOTF), which indicates the ratio between the optical brightness information on the recording side (scene light) and the optical brightness information on the display side (display light). If the inverse of the OETF is used as EOTF, the result is a linear OOTF. However, in television systems, the displayed light out of a television display is not linearly related or proportional to the light captured by the camera. A linear reproduction of the scene light on a display would lead to a low contrast washed out image. In addition, the perception of brightness usually differs between camera and display environments, leading to wrong image impressions during reproduction on a monitor. For this reason, an overall non-linearity is applied by imposing the rendering intent using a “reference” OOTF, which compensates for the issue of linearity between scene light and display light as well as the difference in tonal perception between these two environments. Specifying and using such a reference OOTF allows consistent end-to-end image reproduction, which is important in television production. In addition, adjustments of artistic kind can be made to further improve the image impression. These artistic adjustments, e.g. those that are made by using the processing parameters of the HDR STATIC Constellation, also affect the OOTF, which then can be called "artistic OOTF". In general, artistic adjustments to the OOTF may be applied either before the reference OOTF on recording side or after the reference OOTF on display side, but significantly depend on the OETF and EOTF in use. Basically, the OOTF aims to apply the "rendering intent" and is generally considered to be a concatenation of the OETF, artistic adjustments and the EOTF. So, the OOTF maps relative scene linear light to display linear light and may also be applied either in the camera on recording side (PQ) or in the display on reproduction side (HLG), as shown in the following figure and described in chapter 3.2.1. “PQ” and 3.2.2. “HLG”. In general, this topic is specified in more detail in the ITU-Standard ITU-R BT.2100 as well as in ITU Report BT.2390.

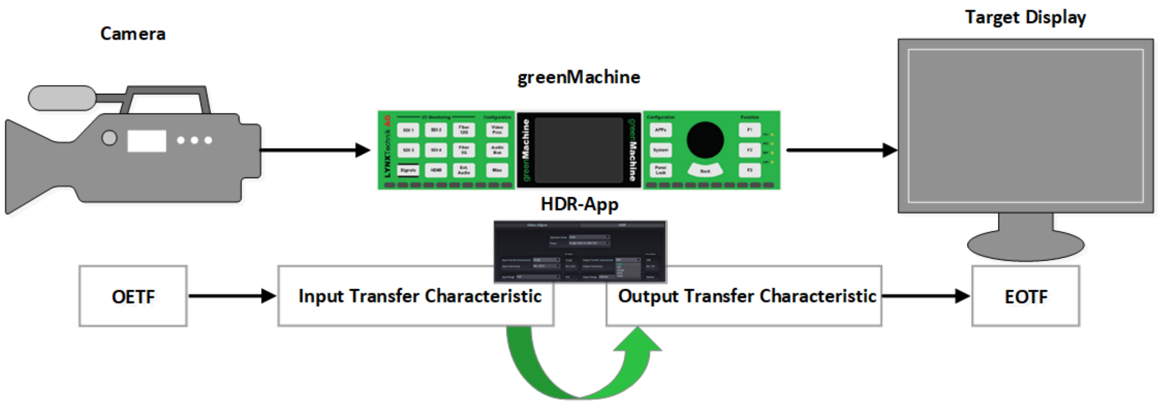


Relationship between OETF, EOTF and OOTF for PQ and HLG according to ITU-R BT.2100 and ITU Report BT.2390

In the end, the goal is to divide the existing brightness information into a video signal having available certain binary values (bits) according to the given requirements and then convert these signal values back again into suitable brightness information.

Depending on the image material, the camera and/or the target display in use, various adjustments of the transfer characteristic must be made during production process in order to reproduce a signal as it looked like in the original scene or in order to reveal a certain image impression to the viewer. For this reason, the transfer characteristic of a video signal often requires a transformation into another transfer characteristic, e.g. to integrate the signal into another workflow or to enable the signal to be displayed on a certain monitor. Therefore, many possible conversions between capturing and displaying a signal may be required, especially to adapt a captured signal for different target displays, e.g. to display an HDR signal correctly on an SDR display.

At this point, the conversion functionality of transfer characteristics in the HDR processor comes into play. A simple application example, which is shown in the figure below, should clarify the principle of converting transfer characteristics and how the HDR STATIC Constellation works.

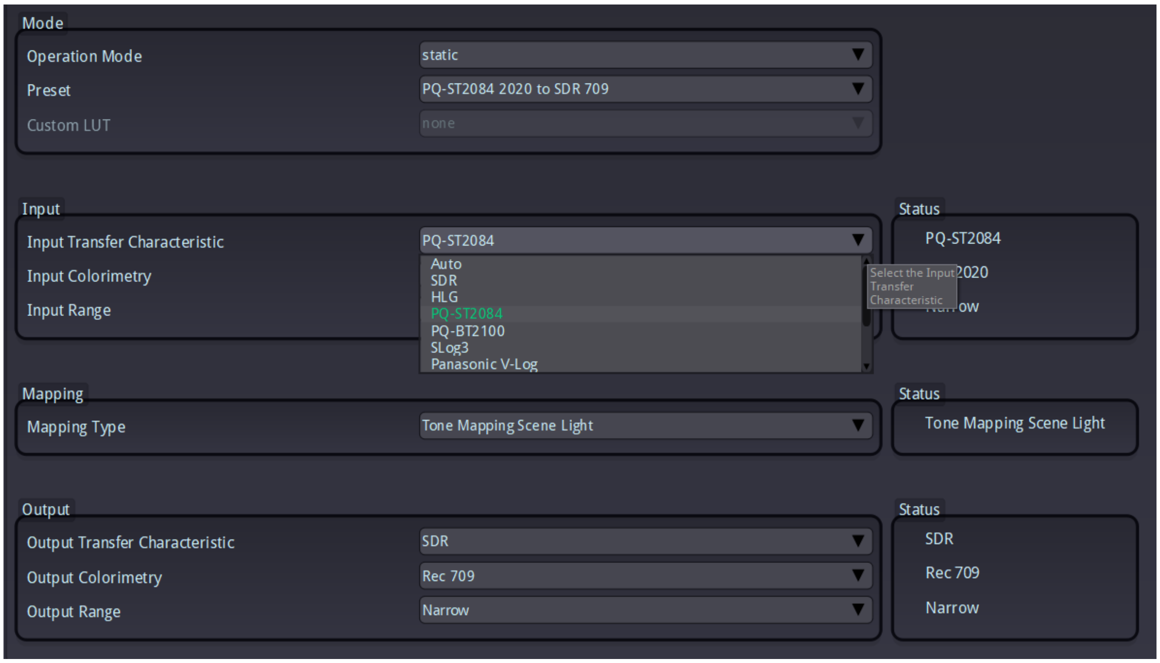


An operation example of transfer characteristics using the HDR processor

If the greenMachine is operated behind a camera like it is shown in the figure above, the "Input Transfer Characteristic" would correspond to the OETF of the camera. Therefore, the "Input Transfer Characteristic" must be selected according to the OETF of the camera. If older, already captured material is present at the input of the greenMachine, the "Input Transfer Characteristic" must be selected according to the characteristic of the material used.

If we stick to our camera example assuming it is an HDR camera capturing with a PQ-ST2084 characteristic curve, a conversion to SDR has to be made in order to reproduce the signal correctly on an SDR display and to display an image impression according to the captured scene. Therefore, the "Input Transfer Characteristic" should be set to "PQ-ST2084", while the "Output Transfer Characteristic" should be set to "SDR" like it is shown in the figure on the following page.

As described in chapter 2.2.2. "Mapping", the HDR STATIC Constellation can either provide a simple direct mapping conversion from PQ-ST2084 (HDR) to Gamma BT.709 (SDR) or a more elaborate static tone mapping operation both in real-time. Since this application example deals with the down-conversion of a camera signal, Tone Mapping should rather be used in such cases, as recommended by ITU Report BT.2408. Thus, the brightness and color information outside the target format will automatically be adjusted in a way that it is not much clipped and fits into the new format. As a result, even the SDR image reproduced on today's SDR devices already benefits greatly from the Tone Mapping of high dynamic range material captured by an HDR camera. Unless the HDR camera signal is required to look similar to a signal delivered by an SDR camera operated without a 'knee'. In this case, according to BT.2408, Direct Mapping should be used. However, using Direct Mapping instead of Tone Mapping would result in lights and shadows of the PQ-ST2084 signal being clipped off quite severely. Whether Direct Mapping or Tone Mapping, in this PQ-ST2084 example the Mapping Type Scene Light must be used in any case, since the Display Light Mapping in combination with PQ-ST2084 is not allowed in the HDR STATIC Constellation (see chapter 2.2.2. "Mapping").



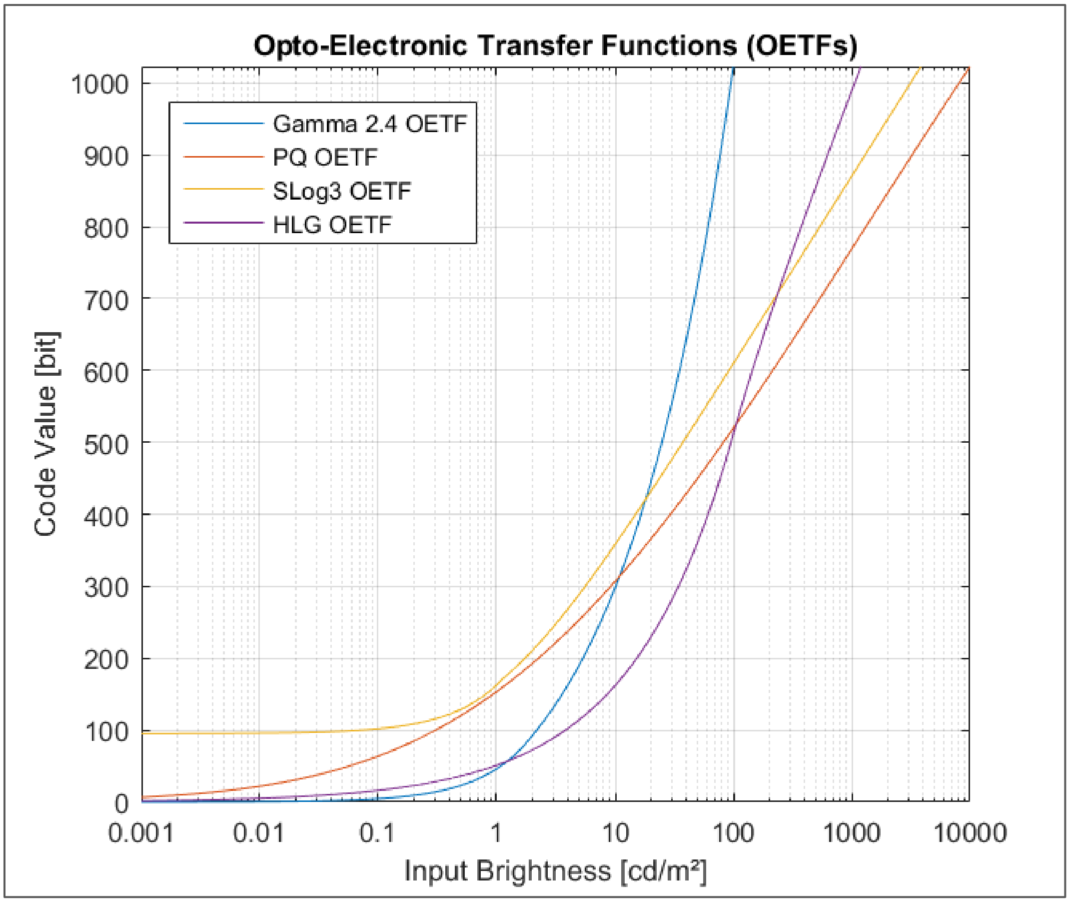
Selecting an Input and Output Transfer Characteristic

However, this example only describes a single case out of many. Particularly for HDR, there are various transfer characteristics that offer various possibilities for scene light being encoded in video signals and video signals being decoded in display light.

The HDR STATIC Constellation is able to perform conversions between all relevant, standardized transfer characteristics. These include – in addition to the standard Gamma BT.709 characteristic for SDR – the characteristic curves PQ* and HLG generally or "officially" standardized for HDR by the ITU as well as common proprietary HDR characteristics like Sony's SLog3. These curves are shown in the figure below as opto-electronic transfer functions (OETFs)**, which illustrate how the incoming brightness values are mapped to the respective code values (in the camera).

**Note:* PQ is available as a transfer characteristic from both the SMPTE ST-2084 standard, which defines PQ as EOTF and OETF as exactly inverse to each other without a reference OOTF or rather with a linear OOTF and the ITU-R BT.2100 standard, which takes the reference OOTF into*

consideration (see chapter 3.2.1. "PQ"). For more details, see ITU standard BT.2100 or ITU Report BT.2390.
***Note: The OETF of PQ is illustrated as simple OETF, i.e. as exactly inverse to the EOTF (as EOTF-1) without consideration of the OOTF (see second figure in this chapter).*

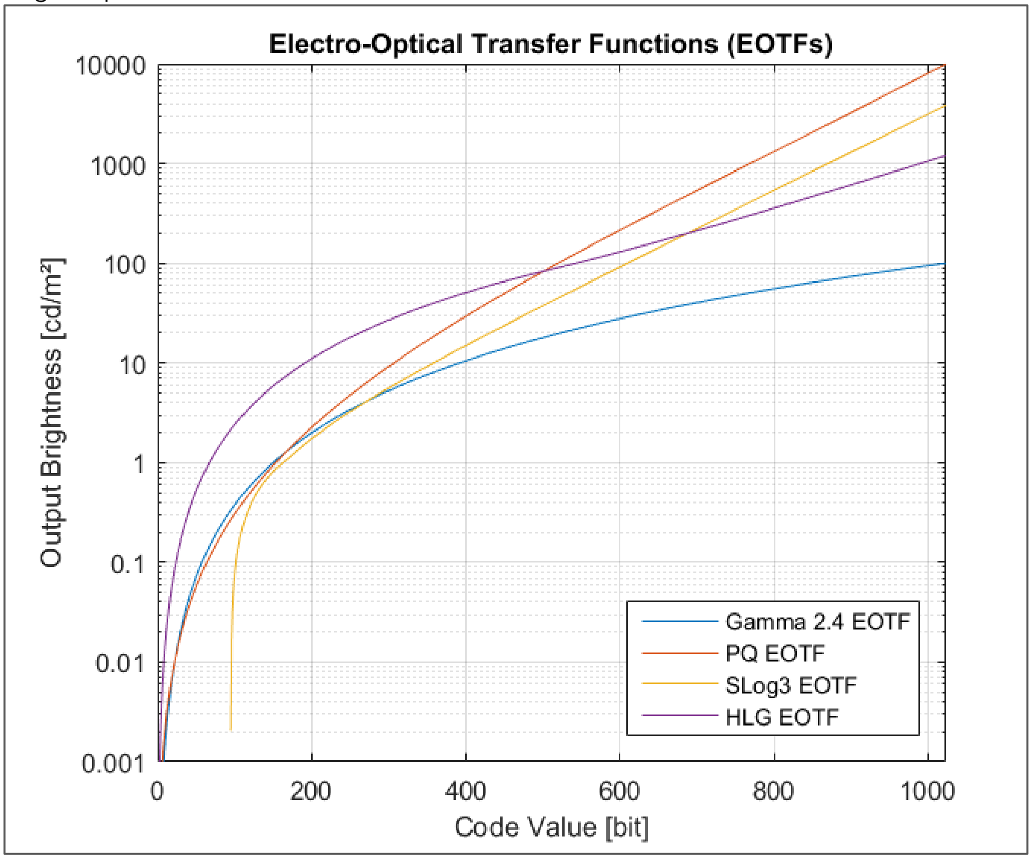


Transfer Characteristics shown as opto-electronic transfer functions (OETFs)

The figure on the following page shows these characteristics as electro-optical transfer functions (EOTFs)*, which illustrate how the encoded values are mapped back to optical brightness information by the respective transfer characteristic (in the display). In these illustrations, the incoming brightness values were normalized between 0 and 1. These curves are already used widely as industry standards for both cameras and displays.

**Note: The EOTF of HLG is illustrated as simple EOTF, i.e. as exactly inverse to the OETF (as OETF-1) without consideration of the OOTF (see second figure in this chapter).*

In addition, the HDR processor is also capable of processing other common proprietary HDR OETFs of camera manufacturers like Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2 and BMD Film. These proprietary curves, except for SLog3, are only available as "Input Transfer Characteristic" but not as "Output Transfer Characteristic", since these curves are only used as OETFs in the cameras on recording side and not as EOTFs for reproduction on the display side. SLog3 is also provided in the HDR processor as "Output Transfer Characteristic", since the SLog3 EOTF is implemented especially in Sony displays and monitors but also in a few others and can therefore be used to display SLog3 material. In the following chapters, the available characteristic curves are considered in more detail.



Transfer Characteristics shown as electro-optical transfer functions (EOTFs)

3.1. SDR (Gamma BT.709)

Standard Dynamic Range (SDR) describes the well-known contrast range, which has been known by television and broadcast for decades. Historically, this range was given by the maximum displayable luminance of 100 cd/m² at this time. This limitation as well as the transfer characteristic (EOTF) used at that time, was due to the properties of the cathode ray tube (CRT). The transfer curve of the CRT, the so-called gamma characteristic, was a physical property and thus an integral part of the former imaging technique by CRTs.

On the recording side, this characteristic has been compensated by a so-called gamma correction, which has found its place as OETF in the cameras. This OETF has been standardized in HDTV standard ITU-R BT.709 and is shown as the blue curve in the OETF figure in the previous chapter.

Due to its non-linearity, the gamma characteristic previously led to a visually improved signal-to-noise ratio in analogue systems of that time. Now the same non-linearity helps to prevent quantization artefacts in today's digital systems. Besides the efficient use of the available range given by SDR, the gamma characteristic is also quite similar to the human visual system. These are the main reasons why this characteristic is still in use for today's SDR-displays.

However, what the CRT has been able to apply by itself, is what today's modern displays such as LCDs and OLEDs must imitate technically. This is the main reason why the gamma characteristic of the CRT has been standardized as EOTF in ITU standard ITU-R BT.1886. As already noted, the gamma characteristic does not go unmentioned in HDTV standard ITU-R BT.709. There it is described as a power function with the exponent 2.4 and quantization of 8-bit (=256 code values) or 10-bit (=1024 code values). BT.709 also contains a reference to the BT.1886 standard. This EOTF gamma characteristic specified by these standards is shown as the blue curve in the EOTF illustration in the previous chapter.

According to ITU Report BT.2390, a reference OOTF corresponding to the gamma characteristic is not explicitly specified. "The reference OOTF is the cascade of the OETF and the EOTF, and the actual OOTF is the cascade of those plus the artistic and display adjustments." Thus, there is also no clearly defined location for a reference OOTF in this system.

Even in today's UHDTV standard ITU-R BT.2020, the gamma characteristic has been standardized but with a quantization of 10-bit (=1024 code values) or 12-bit* (=4096 code values). Therefore, the gamma characteristic in the HDR processor is fully available for all video formats and resolutions (SD, 720p, HD and 4K/UHD).

But when does the use of "SDR" as transfer characteristic become necessary?

**Note: Since 12-bit quantization is not yet relevant today and is not yet supported by the greenMachine, this is not further covered in this manual.*

3.1.1.Use cases for "SDR"

As there are still plenty of SDR devices existing today, the Gamma BT.709 standard is not obsolete at all. In order to ensure the compatibility between these devices and the new HDR formats, an HDR-to-SDR down-conversion is very important.

As described in more detail in chapter 2.2.2. "Mapping", the HDR STATIC Constellation can either provide a simple direct mapping conversion or a more elaborate static tone mapping operation both in real-time. While Direct Mapping would result in lights and shadows outside the SDR format being clipped off quite severely, Tone Mapping automatically adjusts the brightness and colour information outside the target format in a way that it is not much clipped and fits into the new format. As a result, image quality and viewing experience on common SDR devices already benefit from converting an HDR signal to the SDR format. Another, more accurate example of down-converting a signal has already been described in chapter 3. “Transfer Characteristics”.

If SDR is selected at the input side, an SDR-to-HDR up-conversion may be performed as well. In this case, Direct Mapping preserves the appearance of the SDR content so that the up-converted HDR version displayed on an HDR monitor will almost look identical to the original SDR version displayed on an SDR monitor. Nevertheless, the result can be a bit dark and may need to be manually adjusted by processing in order to get better mixed with material from HDR cameras (see chapter 2.2.3. “Processing Parameters”). However, the Tone Mapping operation automatically creates a stronger HDR look in case of up-conversion. The up-converted signal benefits from the tone mapping and appears more brilliant overall due to the adjustment of luminance.

The “SDR” setting should be selected as “Input Transfer Characteristic” whenever an SDR (Gamma BT.709) signal is present on the input side, or as “Output Transfer Characteristic” whenever an HDR-to-SDR down-conversion is required. If SDR is selected at both “Input” and “Output Transfer Characteristic”, the system will basically bypass.

The operations behind these conversions as well as the resulting looks in the context of the available Mapping Types have already been discussed in more detail in chapter 2.2.2. “Mapping”. The operations and resulting looks in the context of Scene Light and Display Light Mapping between SDR (Gamma BT.709), PQ and HLG will be discussed in the following chapters (see chapter 3.2.1. “PQ” and 3.2.2. “HLG”).

For more information on HDR-to-SDR down-conversion and SDR-to-HDR up-conversion and their use within production workflows, see ITU Report BT.2408, where the suggested format conversions and the resulting looks (for PQ and HLG production) are described in detail. For more detailed technical descriptions on how Scene Light and Display Light Mapping is being processed in the context of SDR (Gamma BT.709), see ITU Report BT.2390.

As already mentioned, the HDR STATIC Constellation provides the SDR format for all video formats and resolutions like SD, 720p, HD, and 4K/UHD.

An overview of the existing use cases of transfer characteristics is also given in chapter 3.4. “Use cases”.

3.2. HDR

The dynamic range of modern HDR video cameras is considerably greater than can be conveyed by a video signal using a conventional OETF gamma curve. This is one of the main reasons why the specification of new HDR transfer characteristics was required.

HDR has technically been specified in ITU-R BT.2100 containing the transfer characteristics PQ and HLG as OETF and EOTF (respectively with reference OOTF) and providing a quantization of 10-bit (see chapters 3.2.1. “PQ” and 3.2.2. “HLG”). However, BT.2100 also specifies 12-bit coding, which is not further mentioned in this manual, as 12-bit is not yet relevant today and is not yet supported by the greenMachine.

In the case of today’s 10-bit, this results in a total of 1024 code values, which are theoretically available for encoding brightness and color information. In fact, there is a limitation of this range given by the UHDTV standard ITU-R BT.2020, whereas BT.2100 allows the entire range to be used as well. We will go into more detail on this issue in chapter 6. “Signal Range”.

In contrast to the usual 8-bit quantization (256 code values) of the gamma characteristic in SDR reproduction, the new HDR standard enables four times the amount of code values now.* As a result, four times the number of brightness information can be encoded, providing more values for brighter image information and more intermediate values for finer gradations in bright and dark image areas. How these gradations in these areas exactly occur and therefore how the brightness information is divided (coded) into the 1024 code values, depends on the transfer characteristic used.

**Note: This statement refers in particular to the playback of SDR and HDR material. In the context of production, SDR is usually processed in 10-bit, too (in accordance with BT.601 and BT.709).*

Furthermore, the BT.2100 standard only specifies HD and 4K/UHD formats for the use of HDR transfer characteristics. There is no specification for lower image resolutions existing, which is why the HDR STATIC Constellation provides the HDR transfer characteristics (PQ-ST2084, PQ-BT2100, HLG and the proprietary characteristics of the camera manufacturers such as SLog3 by Sony, Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2 and BMD Film) for HD and 4K/UHD footage only. The use of HDR characteristics for SD or 720p material is not supported by the HDR processor, so these transfer characteristics are not available for these cases.

An overview of all invalid cases is contained in the tables of the appendix.

For HDR, unlike SDR, there are significantly more approaches to transfer characteristics existing. As a result, more transfer curves and more options are available compared to classic SDR. The characteristics of HDR and therefore the resulting image impression strongly depend on these transfer curves. This is the reason why the HDR STATIC Constellation also enables cross-conversion* functionality between available HDR characteristics.

**Note:* A cross-conversion only supports Direct Mapping since there is no need for a brightness correction by a tone mapping operation in this case (see chapter 2.2.2. “Mapping”).*

Furthermore, the HDR STATIC Constellation offers the ability to perform up-conversions from SDR to HDR as well as down-conversion from HDR to SDR. In order to ensure compatibility between SDR devices and the new HDR formats, HDR-to-SDR down-conversion has become very important. As described in more detail in chapter 2.2.2. “Mapping”, the HDR STATIC Constellation can either provide a simple direct mapping conversion or a more elaborate static tone mapping operation both in real-time. While Direct Mapping would result in lights and shadows outside the SDR format being clipped off quite severely, Tone Mapping automatically adjusts the brightness and color information outside the target format in a way that it is not much clipped and fits into the new format. As a result, image quality and viewing experience on common SDR devices already benefit from converting a signal from HDR to SDR. Another, more accurate example of down-converting a signal has already been described in chapter 3. “Transfer Characteristics”.

In order to match SDR material to HDR material, an SDR-to-HDR up-conversion is required, which can also be performed using either Direct Mapping or Tone Mapping. Thus, material from both standards can be mixed well with each other. In this case, Direct Mapping preserves the appearance of the SDR content so that this up-converted HDR version displayed on an HDR monitor will almost look identical to the original SDR version displayed on an SDR monitor. Nevertheless, the result can be a bit dark and may need to be manually adjusted by processing in order to get better mixed with material from HDR cameras (see chapter 2.2.3. “Processing Parameters”). However, the Tone Mapping operation automatically creates a stronger HDR look in case of up-conversion. The up-converted signal benefits from the tone mapping and appears more brilliant overall due to the adjustment of luminance. More information about the advantages and disadvantages of both methods is given in chapter 2.2.2. “Mapping”.

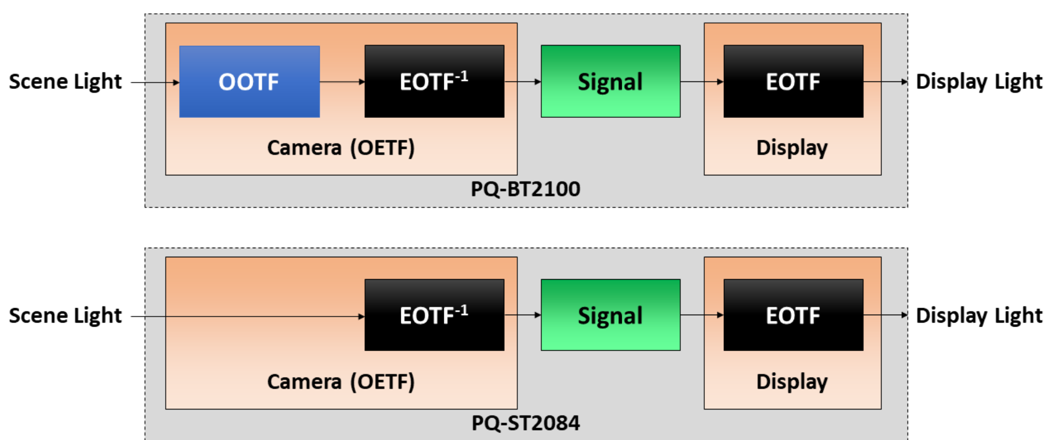
With PQ and HLG as “officially” standardized HDR characteristics by the ITU and the common proprietary HDR characteristics of camera manufacturers like Sony’s SLog3, Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2 and BMD Film, the HDR STATIC Constellation includes all relevant representatives in today’s HDR format.

However, it should be noted that, except for SLog3, the HDR STATIC Constellation only offers the possibility to make use of the proprietary characteristics as “Input Transfer Characteristic” on the input side, but not as “Output Transfer Characteristic”. This is because these curves are only used as OETFs in the cameras on recording side and not as EOTFs for reproduction on the display side (see chapter 3. “Transfer Characteristics” and 3.2.4. “Other manufacturers’ characteristics”). SLog3 is provided in the HDR processor as “Output Transfer Characteristic”, since the SLog3 EOTF is implemented especially in Sony displays and monitors but also in a few others and can, therefore, be used to display SLog3 material (see chapter 3.2.3. “SLog3”).

The available HDR characteristics are described in more detail in the following chapters.

3.2.1.PQ

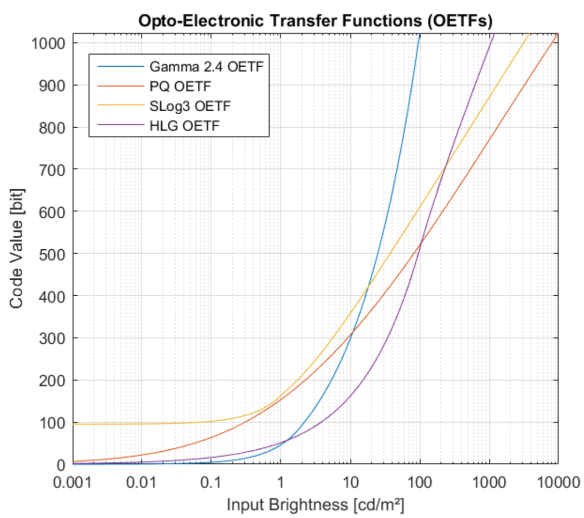
Dolby's perceptual quantizer (PQ) has been standardized by the SMPTE as SMPTE ST-2084 as EOTF and OETF. In this standardization the OETF is considered to be the exact inverse of the EOTF, resulting in a linear OOTF, i.e. no reference OOTF is applied (see chapter 3. “Transfer Characteristic”) as shown in the following figure. The standard is based on the Barten characteristic, which depicts the functioning of human brightness perception in a complex and modern model. In addition, PQ is based on an SMPTE and Dolby subject study to determine audience preference over the required dynamic range. Since the study showed that viewers prefer a luminance range between 0.001 cd/m² and 10,000 cd/m², the standard covers exactly this dynamic range.

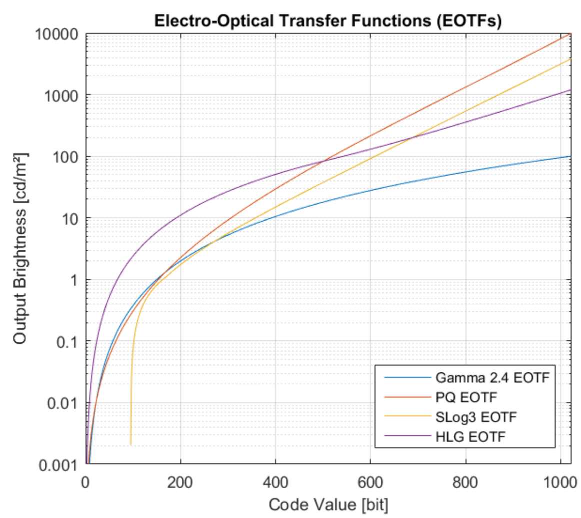


Difference between PQ-BT2100 and PQ-ST2084

Furthermore, the ITU's HDR standard, ITU-R BT.2100, specifies PQ as a 10-bit EOTF and OETF as well, but in combination with a reference OOTF as described in chapter 3. “Transfer Characteristics” and shown in the figure above. The OOTF being considered in the camera (or being imposed in the production process), makes PQ a display-related system that is initially designed to provide an intended image impression in a BT.2100 defined reference environment (5 nits or cd/m² around the monitor while avoiding scattered light on the display). This means that the image should, therefore, be adapted according to these reference conditions on the recording side using the reference OOTF, so viewing under these conditions during reproduction leads to an optimized image impression on the reproduction side. Vice versa, this also means that if this reference condition is not fulfilled, the viewer will get a wrong impression of the image. Therefore, PQ as an absolute brightness metric basically ensures that an image is reproduced on all systems with the same absolute luminance, which ensures good comparability. For more details, see ITU standard BT.2100 and ITU Report BT.2390.

The 10-bit PQ characteristic is shown as simple OETF, i.e. as exactly inverse to the EOTF without consideration of the OOTF (as $EOTF^{-1}$) in the OETF figure and as EOTF in the EOTF figure below as well as in chapter 3. “Transfer Characteristics”.





With PQ-ST2084 and PQ-BT2100, the HDR STATIC Constellation offers both the transfer characteristic according to SMPTE ST-2084, which defines PQ as EOTF and OETF as exactly inverse to each other with a linear OOTF or rather without a reference OOTF and the transfer characteristic according to ITU-R BT.2100, which is considered to be EOTF, and OETF in combination with the reference OOTF. PQ-ST2084* or PQ-BT2100 should always be used as “Input Transfer Characteristic” whenever there is a PQ-ST2084 or PQ-BT2100 signal on the input side, or as “Output Transfer Characteristic” when a signal is to be converted to one of these PQ characteristics.

***Note:** *PQ-ST2084 as the most common PQ characteristic, especially on the recording side, should be used as transfer characteristic whenever material is being or has been captured in ST-2084 unless the signal shall be interpreted as PQ-BT2100 to maintain a certain look. Please note the following explanations and notes on this topic, especially in the context of cross-conversion between PQ and HLG.*

A conversion from SDR to PQ-ST2084 or PQ-BT2100 corresponds to an up-conversion and conversely to a down-conversion. A conversion from PQ-ST2084 or PQ-BT2100 to HLG* and SLog3 or vice versa corresponds to a cross-conversion. Conversions between signals captured with other proprietary OETFs of camera manufacturers (Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2, BMD Film) and PQ-ST2084 or PQ-BT2100 signals also correspond to cross-conversions. The topic of up-, down- and cross-conversions has already been dealt with in more detail in chapter 2.2.1 "HDR Conversions", 2.2.2. “Mapping”, 3. "Transfer Characteristics" and 3.1.1. "Use Cases of ‘SDR’". If the same PQ characteristic is selected as both “Input Transfer Characteristic” and “Output Transfer Characteristic” simultaneously, the system will basically bypass the PQ signal being present at the input.

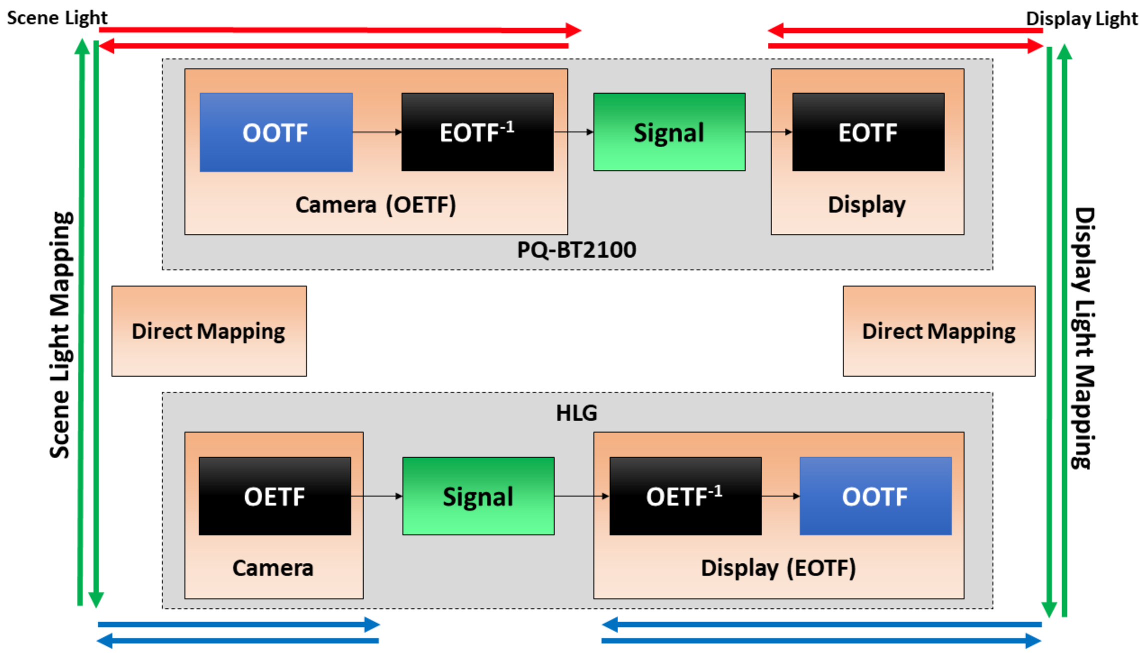
Note:* Basically, an HDR cross-conversion from PQ to HLG should be performed according to the transfer characteristic used during image capture in order to maintain the displayed brightness level in respect of a displayed HLG or PQ signal according to BT.2100. But* **note; *when using PQ-ST2084 as “Input Transfer Characteristic”, the displayed signal after cross-conversion will appear darker in HLG on the same reference monitor than before in PQ. To prevent this and maintain the same brightness level previously displayed on the reference monitor in PQ, PQ-BT2100 must be selected as “Input Transfer Characteristic”. In the opposite case of cross-conversion from HLG to PQ, PQ-BT2100 should be selected to maintain consistent brightness level after cross-conversion. Using PQ-ST2084 in this case would result in the displayed signal being brighter. This is related to the reference OOTF, which is considered by ITU-R BT.2100 in contrast to SMPTE-ST2084. (see further descriptions in this chapter)*

According to ITU Report BT.2390, a cross-conversion between PQ and HLG is referred to as “transcoding”, which “aims to produce identical display light when the transcoded signal is reproduced on a display of the same peak luminance** as the original signal”. This is exactly what Direct Mapping** Display Light does in this case. As described in chapter 2.2.2. “Mapping”, the brightness levels which the input signal would cause on a reference monitor are used as a reference for the mapping.

***Note: To avoid changes in brightness, the Direct Mapping operation works according to ITU Report BT.2390 and the current industry consensus with a reference peak displayed luminance of 1000 cd/m² for HLG and limiting the PQ signal to the same peak luminance of 1000 cd/m², thus achieving consistent brightness.*

According to the descriptions in chapter 2.2.2. “Mapping”, in case of cross-conversion from PQ-BT2100 to HLG, the EOTF of PQ is applied to the signal first (see red arrow at top right in the following figure) in order to derive the display light a monitor would reproduce. After performing the Direct Mapping operation (see the right green arrow), the HLG inverse EOTF ($EOTF^{-1}$ = $OOTF^{-1}$ + OETF) is applied to obtain the equivalent HLG signal (see blue arrow bottom right). When this HLG signal is decoded by the HLG EOTF in the display, the result will be the same display light being produced by decoding the original PQ signal with the PQ EOTF. The whole process can also be performed in the reverse arrow direction in case of cross-conversion from HLG to PQ-BT2100 as described in the following chapter (see 3.2.2. “HLG”).

As already described in chapter 2.2.2. "Mapping", PQ-ST2084 only supports Scene Light Mapping and no Display Light Mapping. If Tone Mapping Display Light or Direct Mapping Display Light is selected in case of conversion with PQ-ST2084, the Mapping Type will be forced to the respective Scene Light Mapping Type. However, according to the first figure in this chapter, Display Light Mapping would be the same operation in both cases anyway, since only the EOTF is applied in both cases in order to derive the required display light a monitor would reproduce.



Cross-conversion between PQ-BT2100 and HLG

Furthermore, a cross-conversion between PQ and HLG can also be performed by using Scene Light Mapping as shown in the figure above. Unlike Display Light Mapping, both transfer characteristics PQ-ST2084 and PQ-BT2100 can be used in the case of Scene Light Mapping. However, it should be noted that this scene-referred operation differs between these two transfer characteristics, as PQ-BT2100, unlike PQ-ST2084, considers the reference OOTF within the OETF in the camera. As described in chapter 2.2.2. “Mapping”, scene-referred mappings are based on the light falling on the camera sensor. Therefore, the brightness levels of the scene must be reconstructed first before the Direct Mapping operation can be performed. According to the descriptions in chapter 2.2.2. “Mapping”, the non-linear process that took place within the camera during image capture must be undone in order to reconstruct the original linear scene light. While PQ-BT2100 requires both the EOTF and inverse OOTF ($OOTF^{-1}$) to be applied (see red arrow at top left), PQ-ST2084 requires only the EOTF to be applied in order to reconstruct the original linear scene light (see first figure in this chapter). After performing the Direct Mapping operation (see left green arrow), the HLG OETF is applied to simulate or rather generate a signal captured by an HLG camera capture curve (see blue arrow bottom left). The whole process can also be performed in the reverse arrow direction in case of cross-conversion from HLG to PQ as described in the following chapter (see 3.2.2. “HLG”).

Since there is no need for a brightness correction in case of cross-conversion, Tone Mapping is not supported in this case. If Tone Mapping Scene Light or Tone Mapping Display Light is selected in the case of cross-conversion, the Mapping Type will be forced to the respective Direct Mapping Type.

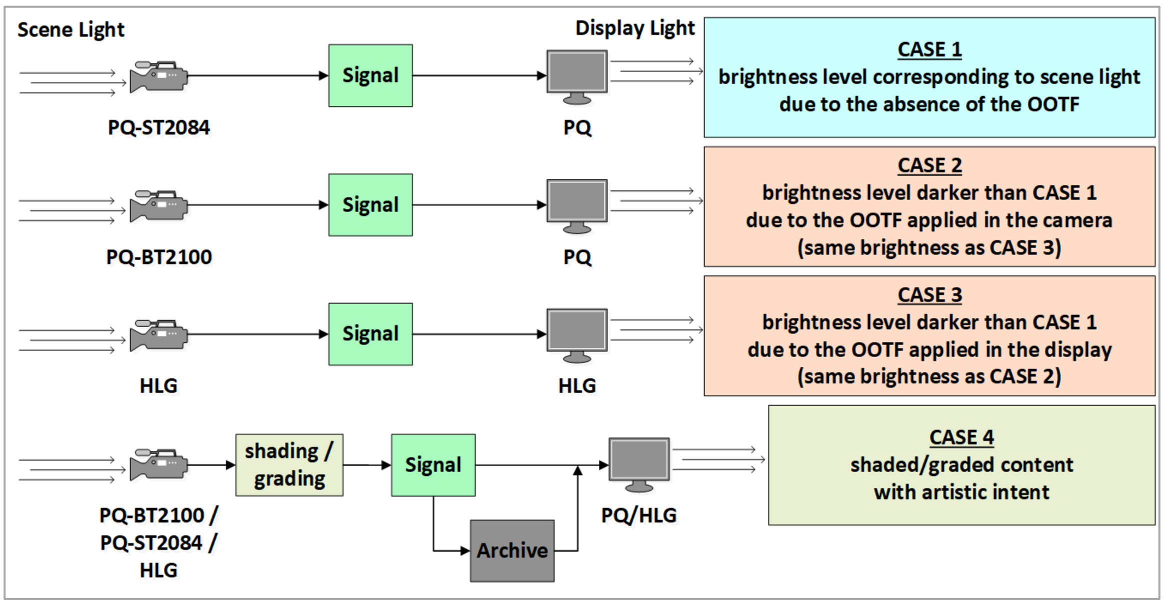
Basically, an HDR cross-conversion from PQ to HLG should be performed according to the transfer characteristic used during image capture in order to maintain the displayed brightness level after cross-conversion in respect of a displayed HLG or PQ signal according to BT.2100 (case 2 and 3 in the following figure). So, PQ-ST2084 should be selected as “Input Transfer Characteristic” if a PQ-ST2084 signal is present at the input of the HDR processor and PQ-BT2100 should be selected if a PQ-BT2100 signal is present on the input side of the processor. However, it should be noted that using PQ-ST2084 as “Input Transfer Characteristic” will result in the displayed signal appearing darker in HLG on the same reference monitor than it previously appeared in PQ. To prevent this and maintain the same brightness level previously displayed on the reference monitor in PQ, PQ-BT2100 must be selected as “Input Transfer Characteristic”. In the opposite case of cross-conversion from HLG to PQ, PQ-BT2100 should be selected to maintain consistent brightness level after cross-conversion. Using PQ-ST2084 in this case would result in the displayed signal being brighter. This is related to the reference OOTF, which is considered when capturing with PQ-BT2100 in contrast to capturing with PQ-ST2084. What happens when PQ-BT2100 signals are interpreted as PQ-ST2084 and PQ-ST2084 signals are interpreted as PQ-BT2100 and how this affects the resulting looks is described in more detail later on in this chapter.

For a more detailed description on cross-conversion (“transcoding”) between PQ-BT2100 and HLG see ITU Report BT.2390.

The process of Scene Light and Display Light Mapping has also been described in more detail in chapter 2.2.2. “Mapping” by using another PQ example. In this example the case of HDR-to-SDR down-conversion from PQ-BT2100 to SDR (Gamma BT.709) is explained in more detail. The opposite case of SDR-to-HDR up-conversion from SDR (Gamma BT.709) to PQ-BT2100 can also be retraced quite well by using the corresponding figure. In the case of a scene-referred conversion between PQ-ST2084 and SDR (Gamma BT.709) the missing OOTF in the recording process of PQ-ST2084 must again be considered as described in the cross-conversion example of this chapter.
While Display Light Mapping tends to preserve the look created by the transfer characteristic used by the display (plus artistic intent), Scene Light Mapping tends to represent the look of the signal being converted to. In the case of HDR-to-SDR down conversion from PQ to SDR (Gamma BT.709), Display Light Mapping would, therefore, lead to a PQ look, while Scene

Light Mapping would result in a “traditional” BT.709 look. However, in the latter case, the resulting look depends on which system the shading takes place (HDR or SDR) and whether artistic intents have already been included during capturing process. In the opposite case of SDR-to-HDR up-conversion from SDR (Gamma BT.709) to PQ, Display Light Mapping would result in the “traditional” BT.709 look, while Scene Light Mapping would lead to a PQ look.

The looks resulting from PQ-BT2100 workflows, i.e. caused by conversions of all kinds from or to PQ-BT2100, are summarized and described in detail in ITU Report BT.2408. However, since this report does not refer to SMPTE ST-2084, the looks resulting from PQ-ST2084 in relation to PQ-BT2100 are described in the following.



Relevant cases of PQ and HLG looks

In general, an image captured by PQ-ST2084 is brighter than an image captured by PQ-BT2100. The reason why the image resulting from PQ-BT2100 is darker is because of the decrease in brightness due to the reference OOTF of PQ-BT2100 (see diagram above). If a signal captured with PQ-ST2084 is interpreted as a PQ-BT2100 signal during playback on the display, no further difference will occur. The same applies to the interpretation of a PQ-BT2100 signal as PQ-ST2084 in the display. This is due to the fact that the EOTF applied by the display is exactly the same in both cases PQ-ST2084 and PQ-BT2100 as shown in the first figure of this chapter. The PQ-BT2100 signal will, therefore, look as much darker than the PQ-ST2084 signal regardless of which EOTF standard will be used within the display. However, in case of HDR-to-SDR down-conversion from PQ to SDR, it strongly depends on how the signal is interpreted and especially which Mapping Type, Scene Light or Display Light is selected. Thus, the selection of the Mapping Type influences the look of the resulting image. If a PQ-ST2084 signal is present at the input of the HDR processor, it should be interpreted as PQ-ST2084 in order to maintain the displayed brightness level in respect of a displayed SDR signal according to BT.709/BT.1886.*

**Note:* *When PQ-BT2100 is selected instead, the displayed signal will appear brighter after down-conversion. This is related to the reference OOTF, which is considered by ITU-R BT.2100 in contrast to SMPTE-ST2084.*

Due to the ability in the HDR STATIC Constellation to interpret a PQ-ST2084 signal as PQ-BT2100 the following table provides information on how the respective interpretations and Mapping Types affect the image in relation to each other.

PQ-ST2084/BT2100 → SDR			to SDR
from	PQ-ST2084	Scene Light Mapping	• lowest image brightness • high contrast • highest saturation level
	PQ-BT2100	Display Light Mapping	• medium image brightness • low contrast • medium saturation level
		Scene Light Mapping	• highest image brightness • low contrast • lowest saturation level

Resulting looks after HDR-to-SDR down-conversion regarding PQ-ST2084 and PQ-BT2100 with the corresponding Mapping Types Scene Light and Display Light

The reason why the result of Scene Light Mapping appears darkest with PQ-ST2084 and brightest with PQ-BT2100 is due to the fact that no inverse reference OOTF is applied when reconstructing the scene light with PQ-ST2084, whereas the reference OOTF is taken into account using PQ-BT2100. The relationships provided in the table are also valid in case of a PQ-BT2100 signal being present at the input of the HDR processor except for the results being equally darker overall compared to a PQ-ST2084 signal being present at the input. As already mentioned, this is because the image resulting from PQ-BT2100 is generally darker due to the reference OOTF included. However, if a PQ-BT2100 signal is present at the input of the HDR processor, it should be interpreted as PQ-BT2100 in order to maintain the displayed brightness level in respect of a displayed SDR signal according to BT.709/BT.1886.

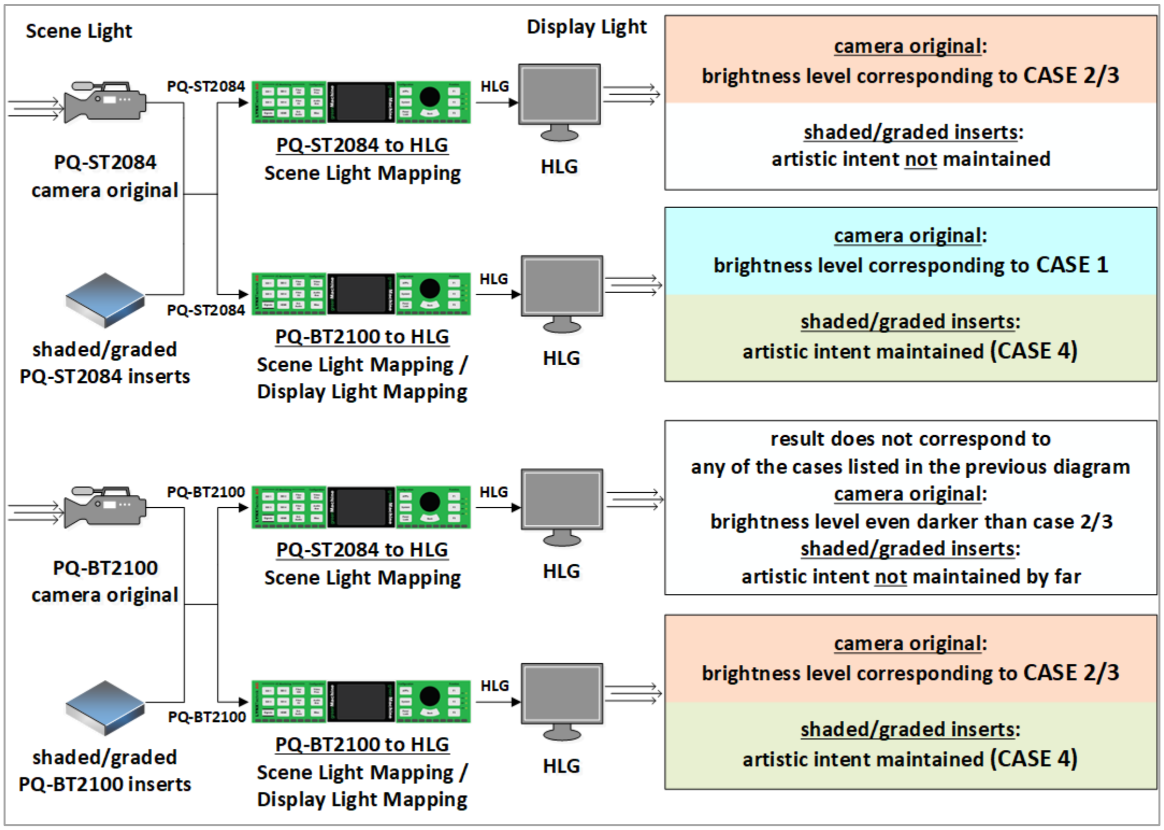
However, the HDR STATIC Constellation offers the ability to interpret PQ-BT2100 signals as PQ-ST2084 as well.* As one would expect, the opposite case of SDR-to-HDR up-conversion from SDR to PQ leads to the exact opposite in terms of the resulting looks as shown in the following table.

**Note:* In this case, the displayed signal will appear darker after down-conversion as shown in the table on the previous page. This is related to the reference OOTF, which is considered by ITU-R BT.2100 in contrast to SMPTE-ST2084.*

<table>
<tr><td colspan="3" rowspan="2">SDR → PQ-ST2084/BT2100</td><td colspan="2">to</td></tr>
<tr><td>PQ-ST2084</td><td>PQ-BT2100</td></tr>
<tr><td rowspan="2">from</td><td rowspan="2">SDR</td><td>Scene Light Mapping</td><td>• highest image brightness
• low contrast
• lowest saturation level</td><td>• lowest image brightness
• high contrast
• highest saturation level</td></tr>
<tr><td>Display Light Mapping</td><td>-</td><td>• medium image brightness
• low contrast
• medium saturation level</td></tr>
</table>

Resulting looks after SDR-to-HDR up-conversion regarding PQ-ST2084 and PQ-BT2100 with the corresponding Mapping Types Scene Light and Display Light

As described earlier in this chapter, an HDR cross-conversion from PQ to HLG should be performed according to the transfer characteristic used during image capture in order to maintain the displayed brightness level after cross-conversion in respect of a displayed HLG or PQ signal according to BT.2100. However, it should be noted that using PQ-ST2084 as “Input Transfer Characteristic” will result in the displayed signal being darker in HLG on the same reference monitor than it previously appeared in PQ. Therefore, e.g. graded inserts or shaded content will appear darker due to the additional OOTF added during cross-conversion from PQ-ST2084 to HLG. If this change in brightness is not desired, e.g. as an artistic intent, PQ-BT2100 should be selected as “Input Transfer Characteristic” to prevent such a change in brightness. Therefore, and to be able to make use of the OOTF as an artistic intent, the HDR STATIC Constellation offers the ability to interpret PQ-ST2084 signals as PQ-BT2100 and PQ-BT2100 signals as PQ-ST2084 even in this case. If a PQ-ST2084 signal is interpreted as PQ-BT2100 in this case of cross-conversion, the result is consistent on the same reference monitor, but in respect of a displayed HLG or PQ signal according to BT.2100, the image will appear brighter. If a PQ-BT2100 signal is interpreted as PQ-ST2084 the image will appear equally darker in respect of both perspectives since they are the same in this case. These correlations can be seen in the following diagram, which refers to the diagram on page 34 (both diagrams are also attached in the appendix to provide a better overview). In the opposite case of HDR cross-conversion from HLG to PQ, PQ-BT2100 should be selected to maintain consistent brightness level after cross-conversion. If PQ-ST2084 is selected in this case of cross-conversion, the result will appear brighter.



Resulting looks when cross-converting from PQ to HLG
in relation to the cases shown in the diagram on page 34

It should also be noted that after “round-tripping” (SDR>PQ>SDR) within a production using Display Light Mapping for up-conversion and Scene Light Mapping for down-conversion, any SDR material (e.g. graded inserts or graphics) will appear slightly less saturated than intended in case of PQ production at the end of the signal chain compared to the original SDR version. For this reason, scene light and display light conversion in combination should be used with care and multiple conversions of such kind should be avoided.

According to ITU Report BT.2408, using PQ as a full range signal is beneficial providing an incremental advantage against the visibility of banding/contouring and in terms of processing. Since the range of PQ signals is as large as it is, it is rare for content to contain pixel values close to the extreme values of the range. Therefore, over- and under-shoots are unlikely to be clipped. More information about this topic can be found in chapter 6. "Signal Range" and 6.1. "Narrow Range".

For more information on suggested format conversions and resulting looks in PQ production, see ITU Report BT.2408. For more detailed technical descriptions on how conversions concerning PQ are being processed, see ITU Report BT.2390.

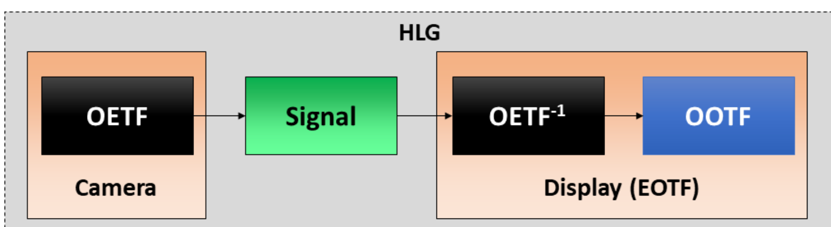
3.2.2.HLG

Hybrid Log Gamma (HLG) is an evolutionary approach developed jointly by the BBC and the NHK. As the name implies, HLG is a combination of gamma manipulation in the dark and logarithmic coding in the bright areas of the curve. This guarantees on the one hand a certain compatibility with existing systems and workflows and on the other hand, the logarithmic encoding "in the lights" and a pure square root OETF "in the blacks" allows an extended dynamic range in contrast to the SDR gamma characteristic*.

**Note: In contrast, the SDR OETF uses a linear portion near black to avoid excessive noise amplification.*

According to BT.2390, the signal characteristic of HLG is similar to that of a traditional standard dynamic range camera with a 'knee'" and is "therefore compatible with conventional standard dynamic range production equipment, tools and infrastructure". Furthermore, HLG has been designed to provide a certain level of compatibility with BT.2020 SDR displays.

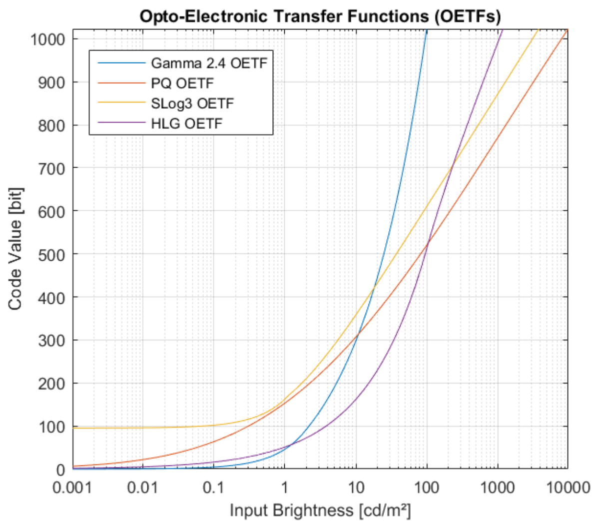
HLG is considered a scene-related system, which is based on the characteristics of the original scene. In simple terms, the signal represents the camera and is adapted by the consumer display to the display's representable luminance range. Therefore, the system was designed in a way that the adaptation of the image impression takes place on the reproduction side, i.e. by the OOTF being considered in the display as shown in the following figure.

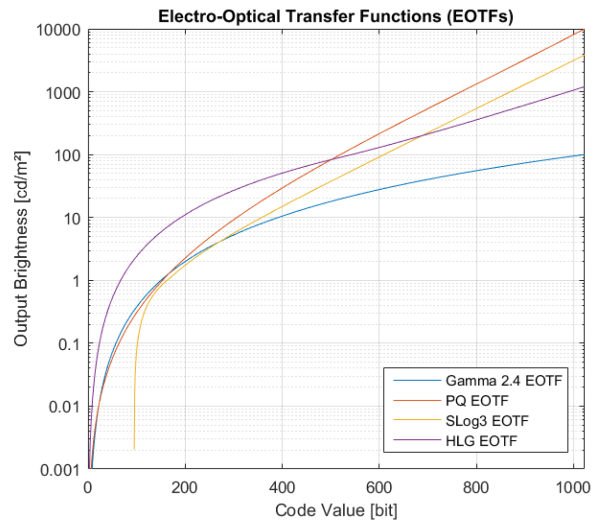


HLG according to ITU-R BT.2100

The image should, therefore, be adjusted in the consumer display based on its representable luminance range using the reference OOTF. This means the mapping of the luminance to the display also includes an adjustment of the OOTF, in which the gamma value is adjusted according to the brightness range of the display. Brighter displays should use an increased gamma, darker displays a lower one. However, the absolute representation of luminance can vary greatly due to the wide variety of conditions appearing on the display side. Therefore, HLG is only considered a relative brightness metric in contrast to PQ as an absolute brightness metric. For more information on the HLG system, see ITU Report BT.2390 and BT.2408.

Just like PQ, this characteristic has also been described as 10-bit OETF and EOTF in the HDR standard ITU-R BT.2100. The 10-bit HLG characteristic is illustrated as OETF and as simple EOTF, i.e. as exactly inverse to the OETF without consideration of the OOTF (as $OETF^{-1}$) in the figures below as well as in chapter 3. “Transfer Characteristics”.



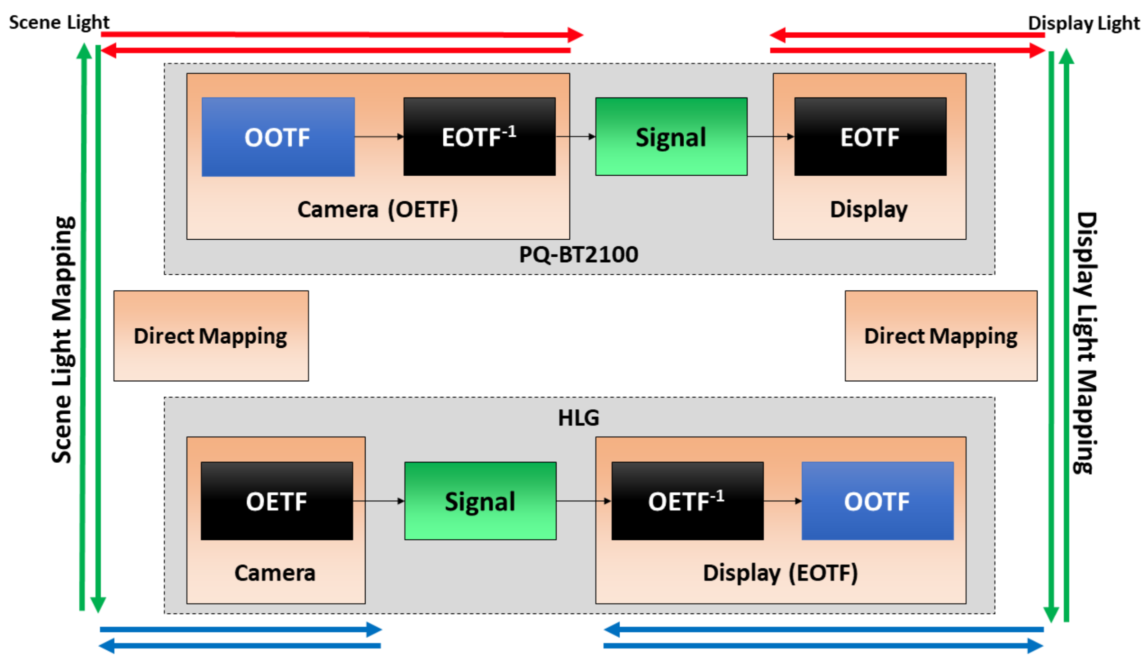


HLG should always be used as “Input Transfer Characteristic” whenever an HLG signal is present on the input side, or as “Output Transfer Characteristic” when a present signal is to be converted to HLG. A conversion from SDR to HLG corresponds to an up-conversion, whereas a conversion from HLG to SDR corresponds to a down-conversion. A conversion from HLG to PQ-ST2084*, PQ-BT2100 and SLog3 or vice versa corresponds to a cross-conversion. The conversion between the other proprietary OETFs of camera manufacturers (Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2, BMD Film) and HLG also corresponds to a cross-conversion. The topic of up-, down- and cross-conversions has already been dealt with in more detail in chapter 2.2.1. “HDR Conversions", 3. "Transfer Characteristics" and 3.1.1. "Use Cases of ‘SDR’". If HLG is selected as both “Input Transfer Characteristic” and “Output Transfer Characteristic” simultaneously, the system will basically bypass the HLG signal being present at the input.

**Note:* *Basically, an HDR cross-conversion from PQ to HLG should be performed according to the transfer characteristic used during image capture in order to maintain the displayed brightness level in respect of a displayed HLG (or PQ) signal according to BT.2100. But* note*; when using PQ-ST2084 as “Input Transfer Characteristic”, the displayed signal after cross-conversion will appear darker in HLG on the same reference monitor than before in PQ. To prevent this and maintain the same brightness level previously displayed on the reference monitor in PQ, PQ-BT2100 must be selected as “Input Transfer Characteristic”. In the opposite case of cross-conversion from HLG to PQ, PQ-BT2100 should be selected to maintain consistent brightness level after cross-conversion. Using PQ-ST2084 in this case would result in the displayed signal being brighter. This is related to the reference OOTF, which is considered by ITU-R BT.2100 in contrast to SMPTE-ST2084. Disregarding this recommendation will therefore lead to differences in the brightness level! This topic has already been discussed in more detail in chapter 3.2.1. “PQ”.*

According to ITU Report BT.2390, a cross-conversion between HLG and PQ is referred to as “transcoding”, which “aims to produce identical display light when the transcoded signal is reproduced on a display of the same peak luminance* as the original signal”. This is exactly what Direct Mapping* Display Light does in this case. As described in chapter 2.2.2. “Mapping”, the brightness levels which the input signal would cause on a reference monitor are used as a reference for the mapping.

**Note: To avoid changes in brightness, the Direct Mapping operation works according to ITU Report BT.2390 and the current industry consensus with a reference peak displayed luminance of 1000 cd/m^2 for HLG and limiting the PQ signal to the same peak luminance of 1000 cd/m^2, thus achieving consistent brightness.*



Cross-conversion between HLG and PQ-BT2100

According to the explanations in chapter 2.2.2. “Mapping”, in case of cross-conversion from HLG to PQ, the EOTF of HLG, i.e. the inverse OETF (OETF^{-1}) and the OOTF will be applied to the signal first (see blue arrow bottom right in the figure above) in order to derive the display light a monitor would reproduce. After performing the Direct Mapping operation (see the right green arrow), the PQ inverse EOTF (EOTF^{-1}) is applied to obtain the equivalent PQ signal (see red arrow at top right). When this PQ signal is decoded by the PQ EOTF in the display, the result will be the same display light being produced by decoding the original HLG signal with the HLG EOTF. The whole process can also be performed in the reverse arrow direction in case of cross-conversion from PQ to HLG as described in the previous chapter (see 3.2.1. “PQ”).

As already described in chapter 2.2.2. "Mapping", Display Light Mapping is only supported in combination with PQ-BT2100, not with PQ-ST2084. If Direct Mapping Display Light is selected in case of conversion between HLG and PQ-ST2084, the Mapping Type will be forced to Direct Mapping Scene Light. However, Display Light Mapping would be the same operation in both cases PQ-BT2100 and PQ-ST2084 anyway, since the PQ EOTF is the same in both cases. For more information see chapter 2.2.2. “Mapping” and 3.2.1. “PQ”.

Furthermore, a cross-conversion between HLG and PQ can also be performed by using Scene Light Mapping as shown in the figure on the previous page. Unlike Display Light Mapping, a cross-conversion between HLG and PQ can be performed by using both transfer characteristics PQ-ST2084 and PQ-BT2100 in the case of Scene Light Mapping. However, it should be noted that the results of cross-conversion resulting from these two different transfer characteristics differ in this scene-referred operation, since PQ-BT2100, unlike PQ-ST2084, considers a reference OOTF within the camera’s OETF. As described in chapter 2.2.2. “Mapping”, scene-referred mappings are based on the light falling on the camera sensor. Therefore, the brightness levels of the scene must be reconstructed first before the Direct Mapping operation can be performed. According to the descriptions in chapter 2.2.2. “Mapping”, the non-linear process that took place within the camera during image capture must be undone in order to reconstruct the original linear scene light. Thus, in case of cross-conversion from HLG to PQ the inverse HLG OETF ($OETF^{-1}$) is applied first in order to reconstruct the original linear scene light (see blue arrow bottom left). After performing the Direct Mapping operation (see left green arrow), either the combination of OOTF and inverse EOTF ($EOTF^{-1}$) will be applied in case of using PQ-BT2100 as shown in the figure (see red arrow at top left), or only the inverse EOTF ($EOTF^{-1}$) will be applied in case of using PQ-ST2084 in order to simulate or rather generate a signal captured by a PQ camera capture curve. The whole process can also be performed in the reverse arrow direction in case of cross-conversion from PQ to HLG as described in the previous chapter (see 3.2.1. “PQ”).

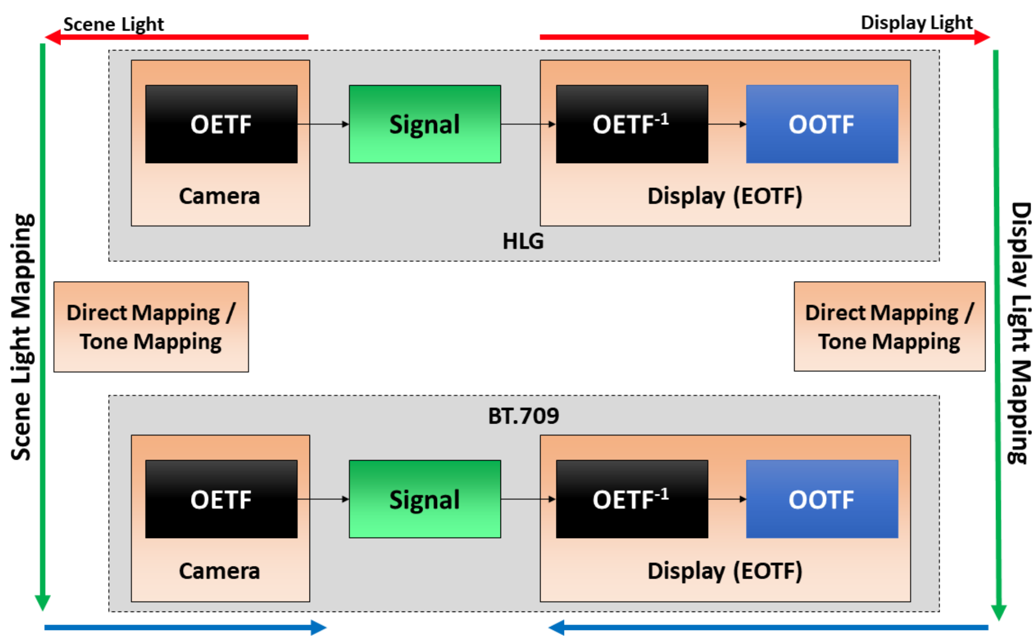
Since there is no need for a brightness correction in case of cross-conversion, Tone Mapping is not supported in this case. If Tone Mapping Scene Light or Tone Mapping Display Light is selected in the case of cross-conversion, the Mapping Type will be forced to the respective Direct Mapping Type.

Basically, an HDR cross-conversion from HLG to PQ should be performed by selecting PQ-BT2100 as “Output Transfer Characteristic” in order to maintain consistent brightness level after cross-conversion. Using PQ-ST2084 in this case would result in the displayed signal being brighter. In the opposite case of cross-conversion from PQ to HLG, the “Input Transfer Characteristic” should be selected according to the PQ transfer characteristic used during image capture to maintain consistent brightness level in respect of a displayed HLG (or PQ) signal according to BT.2100. So, PQ-ST2084 should be selected as “Input Transfer Characteristic” if a PQ-ST2084 signal is present at the input of the HDR processor and PQ-

BT2100 should be selected if a PQ-BT2100 signal is present on the input side of the processor. However, it should be noted that using PQ-ST2084 as "Input Transfer Characteristic" will result in the displayed signal appearing darker in HLG on the same reference monitor than it previously appeared in PQ. To prevent this and maintain the same brightness level previously displayed on the reference monitor in PQ, PQ-BT2100 must be selected as "Input Transfer Characteristic". This is related to the reference OOTF, which is considered when capturing with PQ-BT2100 in contrast to capturing with PQ-ST2084. What happens when PQ-BT2100 signals are interpreted as PQ-ST2084 and PQ-ST2084 signals are interpreted as PQ-BT2100 and how this affects the resulting looks has already been described in more detail in chapter 3.2.1. "PQ".

For a more detailed description on cross-conversion ("transcoding") between PQ-BT2100 and HLG see ITU Report BT.2390.

The process of Scene Light and Display Light Mapping has also been described in more detail in chapter 2.2.2. "Mapping" by using an HDR-to-SDR down-conversion example from PQ-BT2100 to SDR (Gamma BT.709). Using the following figure and the relationships and facts described in this chapter as well as in chapter 2.2.2. "Mapping", the HDR-to-SDR down-conversion from HLG to SDR (Gamma BT.709) can be retraced likewise. The opposite case of SDR-to-HDR up-conversion from SDR (Gamma BT.709) to HLG can also be retraced by using the illustration.



Down-conversion from HLG to SDR (Gamma BT.709)

According to ITU-Report BT.2408 and BT.2390, if no further artistic adjustments are made, HLG signals preserve the chromaticity of the scene as captured by the camera compared to the “traditional” look of SDR cameras. While Display Light Mapping tends to preserve the look created by the transfer characteristic used by the display (plus artistic intent), Scene Light Mapping tends to represent the look of the signal being converted to. In the case of HDR-to-SDR down conversion from HLG to SDR (Gamma BT.709), Display Light Mapping would therefore lead to an HLG look, while Scene Light Mapping would result in a “traditional” BT.709 look. However, in the latter case, the resulting look depends on which system the shading takes place (HDR or SDR) and whether artistic intents have already been included during capturing process. In the opposite case of SDR-to-HDR up-conversion from SDR (Gamma BT.709) to HLG, Display Light Mapping would result in the “traditional” BT.709 look, while Scene Light Mapping would lead to an HLG look.

The looks resulting from HLG workflows, i.e. caused by conversions of all kinds from or to HLG, are summarized and described in detail in ITU Report BT.2408. However, since this report does not refer to SMPTE ST-2084, the looks resulting from cross-conversions between HLG and PQ-ST2084 in relation to PQ-BT2100 are described in the following.

As described earlier in this chapter, an HDR cross-conversion from HLG to PQ should be performed by selecting PQ-BT2100 as “Output Transfer Characteristic” in order to maintain consistent brightness level after cross-conversion. However, in this case of cross-conversion between HLG and PQ the HDR STATIC Constellation offers the ability to use both PQ-BT2100 and PQ-ST2084 as “Output Transfer Characteristic”. If PQ-ST2084 is selected instead of PQ-BT2100 in this case, the result will appear brighter.

In the opposite case of cross-conversion from PQ to HLG, the “Input Transfer Characteristic” should be selected according to the PQ transfer characteristic used during image capture to maintain consistent brightness level after cross-conversion in respect of a displayed HLG (or PQ) signal according to BT.2100. However, it should be noted that using PQ-ST2084 as “Input Transfer Characteristic” will result in the displayed signal being darker in HLG on the same reference monitor than it previously appeared in PQ. Therefore, e.g. graded inserts or shaded content will appear darker due to the additional OOTF added during cross-conversion from PQ-ST2084 to HLG. If this change in brightness is not desired, e.g. as an artistic intent, PQ-BT2100 should be selected as “Input Transfer Characteristic” to prevent such a change in brightness. Therefore, and to be able to make use of the OOTF as an artistic intent, the HDR STATIC Constellation offers the ability to interpret PQ-ST2084 signals as PQ-BT2100 and PQ-BT2100 signals as PQ-ST2084 even in this case. If a PQ-ST2084 signal is interpreted as PQ-BT2100 in this case of cross-conversion, the result is consistent on the same reference monitor, but in respect of a displayed HLG or PQ signal according to BT.2100, the image will appear brighter. If a PQ-BT2100 signal is interpreted as PQ-ST2084 the image will appear equally darker in respect of both perspectives since they are the same in this case. The case of cross-conversion from PQ to HLG has already been discussed in more detail in chapter 3.2.1 "PQ". The chapter also contains diagrams illustrating this case. For more information on this topic and PQ in general, see chapter 3.2.1. “PQ”.

It should also be noted that after “round-tripping” (SDR>HLG>SDR) within a production using Display Light Mapping for up-conversion and Scene Light Mapping for down-conversion, any SDR material (e.g. graded inserts or graphics) will appear more saturated than intended in case of HLG production at the end of the signal chain compared to the original SDR version. For this reason, scene light and display light conversion in combination should be used with care and multiple conversions of such kind should be avoided.

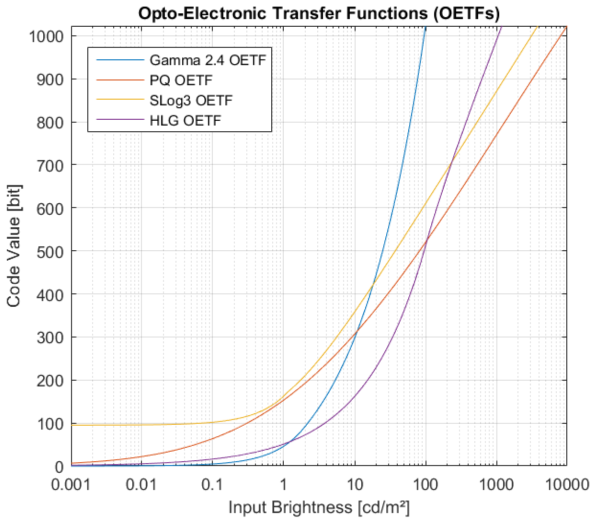
According to ITU Report BT.2408 and specified in ITU Report BT.2390, using narrow range signals is strongly preferred for HLG to maintain signal fidelity and to reduce the risk of confusing full range with narrow range signals (and vice versa) in production. More information about this topic can be found in chapter 6. "Signal Range" and 6.1. "Narrow Range".

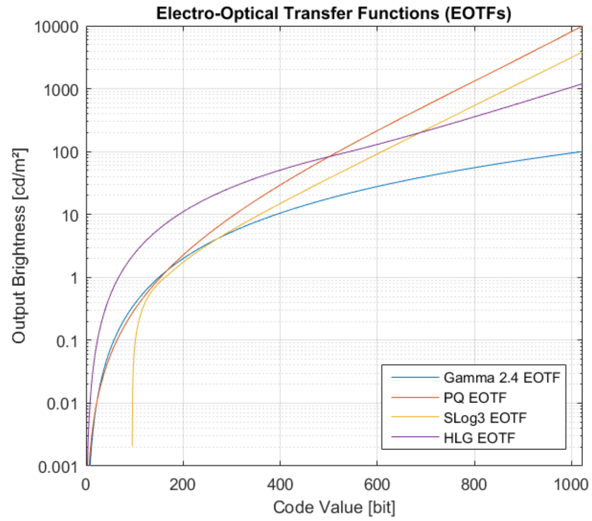
For more information on suggested format conversions and resulting looks in HLG production, see ITU Report BT.2408. For more detailed technical descriptions on how conversions concerning HLG are being processed, see ITU Report BT.2390.

3.2.3.SLog3

SLog3 is a consistently logarithmic transfer characteristic developed by Sony, which is often used in the field of film and scenic productions. On the recording side, the logarithmic characteristic enables the capturing of a very large dynamic range or contrast range and receives a particularly large number of gradations in dark areas. Therefore, SLog3 provides a high contrast, especially in dark areas of the image. The characteristics of the SLog3 curve are comparable to those of scanned film and in consequence, the adaptation of captured SLog3 material is usually done in the context of a more elaborate postproduction.

For capturing with SLog3 the Sony standard provides a 10-bit quantization and only allows the full range, i.e. the use of the entire 10-bit code value range. More on this subject in chapter 6. "Signal Range". The 10-bit SLog3 characteristic is represented as OETF in the following OETF figure and as an inverse function as EOTF in the EOTF figure as well as in chapter 3. “Transfer Characteristics”.





In the HDR STATIC Constellation SLog3 is provided as both “Input Transfer Characteristic” *and* “Output Transfer Characteristic”, since the SLog3 EOTF is implemented in displays and monitors (especially in Sony devices but in a few others as well) and can therefore be used to display SLog3 material.

As already described in chapter 2.2.2. "Mapping", SLog3 only supports Scene Light Mapping and no Display Light Mapping. If Tone Mapping Display Light or Direct Mapping Display Light is selected in case of conversion with SLog3, the Mapping Type will be forced to the respective Scene Light Mapping Type.

SLog3 should always be used as “Input Transfer Characteristic” whenever an SLog3 signal is present on the input side, or as “Output Transfer Characteristic” when a signal is to be converted to SLog3. A conversion from SDR to SLog3 corresponds to an up-conversion, a conversion from SDR to SLog3 corresponds to a down-conversion. A conversion from PQ-ST2084, PQ-BT2100 or HLG to SLog3 or vice versa corresponds to a cross-conversion.

Conversions between the other proprietary OETFs of camera manufacturers (Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2, BMD Film) and SLog3 also correspond to a cross-conversion. The topic of up-, down- and cross-conversion has already been dealt with in more detail in chapter 2.2.1. "HDR Conversions", 2.2.2. “Mapping”, 3. "Transfer Characteristics" and 3.1.1. "Use Cases of ‘SDR’". Examples in the context of Scene Light Mapping, Direct Mapping and Tone Mapping can also be found in chapter 2.2.2. “Mapping” as well as in chapter 3.2.1. “PQ” and 3.2.2. “HLG”. If SLog3 is selected as both “Input Transfer Characteristic” and “Output Transfer Characteristic” simultaneously, the system will basically bypass the SLog3 signal being present at the input.

3.2.4. Other manufacturers' characteristics

Besides SLog3, the HDR processor does support other common proprietary HDR camera capture curves of camera manufacturers such as Panasonic V-Log, Arri LogC, RED Log3G10, Canon C-Log2 and BMD (Blackmagic Design) Film. Since these capture curves (OETFs) originate from the respective cameras and, unlike SLog3, are not used as EOTFs on the display side at all, they are only available as "Input Transfer Characteristic" on the input side.

This is also the reason why the HDR processor does only support these characteristics in combination with Scene Light Mapping and not with Display Light Mapping as already described in chapter 2.2.2. "Mapping". If Tone Mapping Display Light or Direct Mapping Display Light is selected in case of conversion with these characteristics, the Mapping Type will be forced to the respective Scene Light Mapping Type.

Furthermore, the system will not bypass such a characteristic if one of these characteristics is present at the input of the processor and the Output Transfer Characteristic "Auto" is selected. Instead, the system will automatically perform a down-conversion to SDR (Gamma BT.709) if the Operation Mode "static" is active (see chapter 3.3. "Auto").

These proprietary transfer characteristics are also intended for wider dynamic ranges such as the "officially" by the ITU standardized characteristics PQ and HLG. However, since these camera capture curves are consistently logarithmic and are mainly used for film and scenic productions, they show the most similarity to SLog3 and work more or less the same way (see chapter 3.2.3. "SLog3").

These characteristics should always be used as "Input Transfer Characteristic" respectively if one of these characteristics is present on the input side, e.g. by directly connecting a camera capturing with one of these characteristics. Conversions from one of these characteristics to PQ-ST2084, PQ-BT2100, HLG or SLog3 correspond to a cross-conversion, whereas conversions to SDR correspond to a down-conversion. An up-conversion does not exist in this case since these characteristics are only available as "Input Transfer Characteristic". The topic of up-, down- and cross-conversion has already been dealt with in more detail in chapter 2.2.1. "HDR Conversions", 2.2.2. "Mapping", 3. "Transfer Characteristics" and 3.1.1. "Use Cases of 'SDR'". Examples in the context of Scene Light Mapping, Direct Mapping and Tone Mapping can also be found in chapter 2.2.2. "Mapping" as well as in chapter 3.2.1. "PQ" and 3.2.2. "HLG".

Further information about these proprietary transfer characteristics and their properties should be taken from the documentation of the respective manufacturers.

3.3. Auto

By selecting "Auto" as “Input Transfer Characteristic” and/or “Output Transfer Characteristic”, it is possible to use the auto feature of the HDR STATIC Constellation for setting the input and/or output characteristic automatically. With activating “Auto” as “Input Transfer Characteristic”, the HDR processor automatically selects the transfer characteristic of the signal being present at the input.

However, the presence of this information as ancillary data in the video stream, i.e. in the vertical blanking region as VANC (vertical ancillary data) of an SDI signal, is necessary for using this feature.* If the information regarding the transfer characteristic of the signal is not contained in the data stream of the signal, this feature should not be used.

**Note:* *Markings in the VANC are read and inserted by the processor according to ITU-R BT.1120-9 for HD and SMPTE - ST2082-10:2018 for 4K/UHD. These standards allow the markings of SDR BT.709, HLG, PQ and “unspecified”. "Unspecified" is regarded as SLog3 in the HDR processor.*

Using “Auto” as "Input Transfer Characteristic" has the advantage that regardless of which signal is present at the input, it is always ensured that the correct conversion is carried out if the desired "Output Transfer Characteristic" has been selected.

By selecting "Auto" as “Output Transfer Characteristic”, the transfer characteristic at the output is set according to the “Input Transfer Characteristic”, assuming this output format corresponds to one of the standards supported by the HDR STATIC Constellation.** (An overview of all permissible and impermissible combinations can be found in the tables of the appendix.) Therefore, by selecting “Auto” as Output Transfer Characteristic, the transfer characteristic of the input signal is basically bypassed (unless it is one of the manufacturers’ characteristics**), which means that no up-, down- or cross-conversion will be performed. In addition, this feature can be used to bypass HDR characteristics like PQ, HLG and SLog3 and still allows color space and/or range conversions of these HDR signals to be performed. However, it should be noted that the Operation Mode “static” must be selected in order to perform these conversions in connection with HDR characteristics (see chapter 2. “Operation Modes”).

By using “Auto” as both “Input Transfer Characteristic” and “Output Transfer Characteristic” simultaneously, the system will also basically bypass the transfer characteristic of the input signal unless it is one of the manufacturers’ characteristics.**

***Note:** *Since the HDR characteristics of the camera manufacturers are only used as OETFs in the cameras on recording side and not as EOTFs for reproduction on the display side, this feature is not available for these characteristics. If “Auto” is selected as Output Transfer Characteristic and one of these manufacturers’ characteristics is present at the input, the system will automatically perform a down-conversion to SDR (Gamma BT.709) if the Operation Mode “static” is active.*

Note: The Operation Mode "bypass HDR/SDR" prevents up-, down- and cross-conversions of transfer characteristics from being performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In this mode, color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). When using Auto, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.

3.4. Use cases

This chapter summarizes the available use cases of the transfer characteristics in the following tables. The existing limitations regarding transfer characteristics are listed in a separate table with all other limitations of the HDR STATIC Constellation (regarding colorimetry and range) in the appendix at the end of the document.

Conversions:

Conversions		to			
		SDR	PQ	HLG	SLog3
from	SDR	none	up	up	up
	PQ	down	none	cross	cross
	HLG	down	cross	none	cross
	SLog3	down	cross	cross	none
	Manufacturers' characteristics	down	cross	cross	cross

Conversion overview of the available transfer characteristics

Mapping Type (STM = Static Tone Mapping, DM = Direct Mapping):

Mapping Type		to			
		SDR	PQ	HLG	SLog3
from	SDR	none	STM/DM	STM/DM	STM/DM
	PQ	STM/DM	none	DM	DM
	HLG	STM/DM	DM	none	DM
	SLog3	STM/DM	DM	DM	none
	Manufacturers' characteristics	STM/DM	DM	DM	DM

Mapping overview of the available transfer characteristics regarding Direct Mapping and Tone Mapping

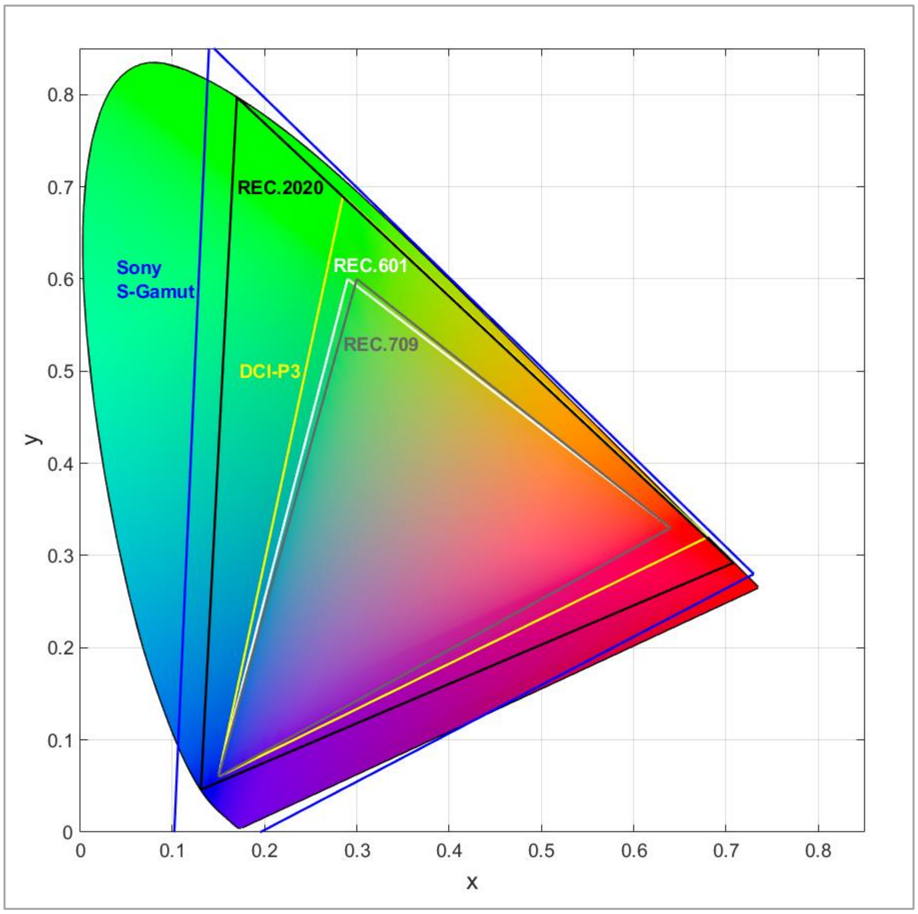
Mapping Type (SL = Scene Light, DL = Display Light)

Mapping Type		to				
		SDR	PQ-ST2084	PQ-BT2100	HLG	SLog3
from	SDR	none	SL	SL/DL	SL/DL	SL
	PQ-ST2084	SL	none	SL	SL	SL
	PQ-BT2100	SL/DL	SL	none	SL/DL	SL
	HLG	SL/DL	SL	SL/DL	none	SL
	SLog3	SL	SL	SL	SL	none
	Manufacturers' characteristics	SL	SL	SL	SL	SL

Mapping overview of the available transfer characteristics regarding Scene Light Mapping and Display Light Mapping

4. Colorimetry / Gamut

As with developments in the brightness range (greater luminance, contrast, and dynamic range), the television and broadcast world is always striving to make progress in the field of colors as well. For example, the ITU's new UHDTV standard BT.2020 has already specified a new and larger color space, commonly known as Rec. 2020. This spans a much larger color triangle in the CIE standard color chart than the former and common Rec. 709 color space of the HDTV standard ITU-R BT.709 (see figure below). In the context of BT.2020 the term "Wide Color Gamut" (WCG) is used quite often as well.



A selection of available color gamuts shown in the CIE chromaticity diagram

The CIE standard color chart shown in the figure above contains all perceptible colors occurring in human color vision. The color triangles within this color chart indicate which and how many of the existing colors can be represented with the respective standard. All colors within a color triangle are specified in the respective standard and theoretically displayable.

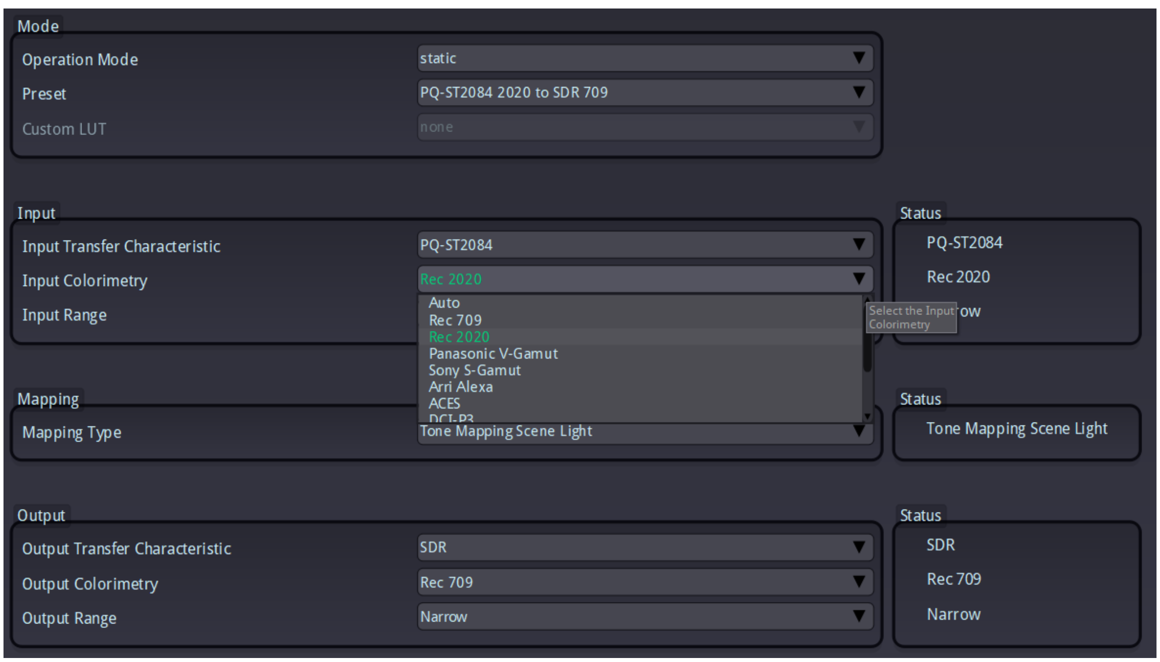
Today's television systems are not 100% capable of displaying all the colors contained in Rec. 2020, but possibly in the future. However, some of the "new" colors can already be viewed on today’s modern television systems.

The HDR STATIC Constellation contains all common and previously specified television color spaces from the past and present, including Rec. 601, Rec. 709 and Rec. 2020, whereas Rec. 601, unlike Rec. 709 and Rec. 2020, cannot actively be selected as “Input” or “Output Colorimetry” in the HDR processor. However, Rec. 601 is automatically detected, selected and processed by the processor whenever an SD signal according to BT.601 is present at the input.

In addition to these television gamuts, the standardized cine gamuts ACES and DCI-P3 are also included in the HDR STATIC Constellation.

According to the common proprietary transfer characteristics of the camera manufacturers described in chapter 3. “Transfer Characteristics” and 3.2.4. “Other manufacturers’ characteristics”, the HDR STATIC Constellation also contains the corresponding color gamuts of these manufacturers, known as Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut and BMD Film.

The HDR STATIC Constellation provides extensive conversion functionality between these different color spaces including all reasonable combinations.

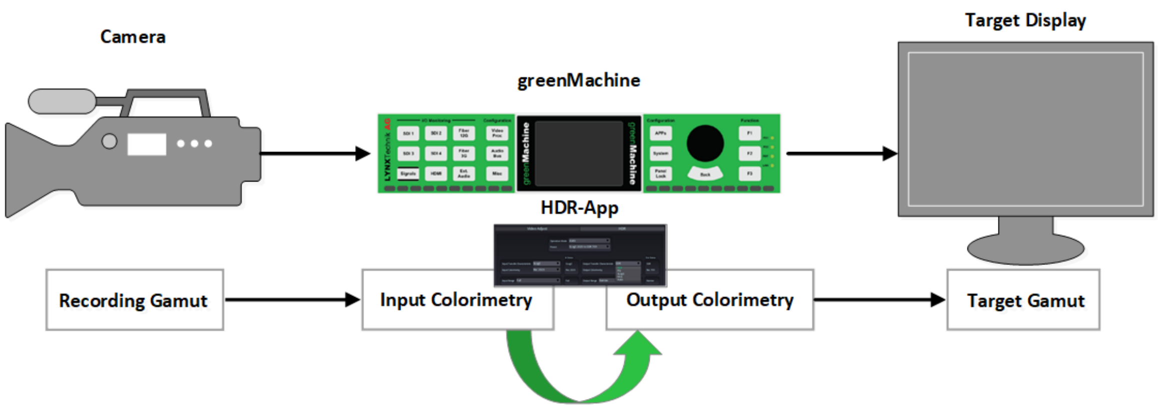


Selecting an Input and Output Colorimetry

The use of the color space conversion should follow a simple principle:
As the selection of the “Input Transfer Characteristic”, the "Input Colorimetry" should also be selected according to the color space of the input signal. If we stick to the example used in chapter 3. "Transfer Characteristics", operating an HDR camera directly in front of the

greenMachine, the "Input Colorimetry" should be selected according to the capture color space used by the camera. Assuming the camera captures in Rec. 2020, “Input Colorimetry” should also be selected as “Rec. 2020”. In order to reproduce colors correctly on a standard SDR display with Rec. 709 color space (or similar), a conversion to Rec. 709 color space must be performed.* Therefore, the "Output Colorimetry" must be set to “Rec. 709”.

**Note: Since the Rec. 2020 color gamut as a wide gamut is significantly larger than the Rec. 709 gamut, a Rec. 2020 input signal may contain color values outside the Rec. 709 gamut. In case of a down-conversion from one of the available wide color gamuts (e.g. Rec. 2020) to Rec. 709, these values outside the Rec. 709 gamut need to be transferred from the wide gamut to the smaller Rec. 709 gamut. This can be done either by a simple “clipping” of the values or by a more elaborate and more appropriate “Gamut Mapping” algorithm (see chapter 4.7. “Gamut Mapping”). Therefore, the “Gamut Mapping” tends to be better suited for “correct” (accurate) color reproduction.*



Operation example for colorimetry using the HDR processor

In general, the “Input Colorimetry” should always correspond to the color space of the incoming video signal, while the “Output Colorimetry” should be selected according to the desired target color space of the target display to be addressed.

Similar to the conversions between transfer characteristics, we also speak of a down-conversion when a wide gamut such as Rec. 2020 is converted to Rec. 709 color gamut, or of an up-conversion when a Rec. 709 signal is converted to Rec. 2020.

The HDR STATIC Constellation allows any up-, down- and cross-conversion in combination with the standardized TV color spaces, except for Rec. 601, since this gamut is only permissible in combination with SD material. Rec. 709 and 2020, on the other hand, can be selected as both input and output colorimetry and can therefore be used in combination with all characteristics.

The HDR STATIC Constellation is also able to perform cross-conversions between cine gamuts (DCI-P3, ACES) or common proprietary color gamuts of camera manufacturers (Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut, BMD Film), which are also intended for wider color gamut, and Rec. 2020* as well as down-conversions between these cine gamuts or proprietary manufacturers’ gamuts and Rec. 709.

However, it should be noted that the cine gamuts as well as the proprietary gamuts of the camera manufacturers are only available on the input side, i.e. as “Input Colorimetry”, since these proprietary camera capture gamuts are only used in the cameras on recording side and not for reproduction on the display side. Thus, even scenic productions that are carried out with cine cameras as well as archive material from scenic productions that has been captured with cine cameras can be transferred to the broadcast standards with their common characteristics, color spaces and ranges. However, since these proprietary gamuts as well as the cine gamuts are only available at the input side of the processor, the system will not bypass such a gamut if one of these gamuts is present at the input of the processor and the Output Colorimetry “Auto” is selected. Instead, the system will automatically perform a down-conversion to Rec. 709 (see chapter 4.6. “Auto”).

***Note: Since these color gamuts differ in size and color chart position, an input signal may contain color values outside the target gamut Rec. 2020. In case of cross-conversion to Rec. 2020, these values need to be transferred from the outside to the boundary or the inside of the Rec. 2020 target gamut. This can be done either by a simple “clipping” of the values or by a more elaborate and more appropriate “Gamut mapping” algorithm (see chapter 4.7. “Gamut Mapping”).*

The standardized broadcast gamuts Rec. 601, Rec. 709 and Rec. 2020. as well as the DCI-P3 cine gamut and the proprietary Sony S-Gamut are illustrated exemplarily in the CIE chromaticity diagram at the beginning of the chapter.

Since the HDR STATIC Constellation does not allow all format combinations arbitrarily, there are also certain restrictions and conditions regarding color space conversions in the HDR processor. The tables in the appendix provide a good overview of the restrictions and conditions being imposed on the executable conversions in the HDR processor.

As described in chapter 2.1. "Operation Mode “bypass HDR/SDR””, color space conversions of SDR (Gamma BT.709) signals are available in both Operation Modes "static" and "bypass HDR/SDR" since the conversion functionality for Colorimetry is also available independently of the HDR STATIC Constellation in the greenMachine and thus remains untouched upon activation of the Operation Mode “bypass HDR/SDR”. If color space conversions are to be performed in connection with HDR characteristics, the Operation Mode “static” must be selected (see chapter 2. “Operation Modes”).

The available color spaces provided by the HDR STATIC Constellation are described in more detail below.

4.1. Rec. 601

The Rec. 601 color gamut has been specified in the ITU standard ITU-R BT.601 for SDTV (Standard Definition Television) as the first television color space defined for digital television. The Rec. 601 color space, which is very similar to the HDTV color space Rec. 709, however, has a slightly different color triangle. While the Rec. 601 color gamut specifies a few more colors in the green-blue area, Rec. 709 defines slightly more colors in the green-red area (see figure at the beginning of chapter 4. “Colorimetry / Gamut”).

Rec. 601 cannot actively be selected as “Input” or “Output Colorimetry” in the HDR STATIC Constellation but is automatically detected, selected and processed by the processor whenever an SD signal according to BT. 601 is present.

4.2. Rec. 709

The Rec. 709 color space has been specified in the ITU standard ITU-R BT.709 and is therefore still valid as today’s HDTV color space. Unlike Rec. 601, Rec. 709 specifies slightly more colors in the green-red area, but fewer colors in the green-blue area. Compared to Rec. 2020, both, Rec. 601 and Rec. 709 contain significantly less colors (see figure at the beginning of chapter 4. “Colorimetry / Gamut”).

Therefore, a conversion from Rec. 709 to Rec. 2020 corresponds to an up-conversion, whereas a conversion from Rec. 2020, DCI-P3, ACES or one of the proprietary camera capture gamuts of the manufacturers (Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut, BMD Film) to Rec. 709 corresponds to a down-conversion.*

Note: *Since these color gamuts are wider than the Rec. 709 color gamut, the input signal may contain color values outside the Rec. 709 gamut. In case of a down-conversion, these values need to be transferred from the wider gamut to the smaller Rec. 709 gamut. This can be done either by a simple “clipping” of the values or by a more elaborate and more appropriate “Gamut Mapping” algorithm (see chapter 4.7. “Gamut Mapping”).*

Basically, Rec. 709 should always be selected as "Input Colorimetry" whenever a Rec. 709 color space signal is present on the input side, or as "Output Colorimetry" when a present signal is to be converted to the Rec. 709 color space. Thus, Rec. 709 can be selected as both input and output colorimetry and can be used in combination with all transfer characteristics provided by the HDR STATIC Constellation. If Rec. 709 is selected as both

"Input Colorimetry" and "Output Colorimetry" simultaneously, the system will basically bypass the Rec. 709 signal being present at the input.

However, it should be noted that Rec. 709 has been standardized for HD signals only, but not for SD and 4K/UHD resolutions. In the HDR STATIC Constellation, the combination of the Rec.709 color gamut with 4K/UHD material is still permissible, since the combination of 4K/UHD and SDR is classified as admissible as described in chapter 3.1. "SDR (Gamma BT.709)". The combination of Rec. 709 with a 720p signal according to SMPTE standard is also permissible in the processor. Only the combination of Rec. 709 and SD material is considered inadmissible in the HDR STATIC Constellation and therefore cannot be selected. These and all other functional limitations of the HDR STATIC Constellation as well as all possible combinations have been compiled and illustrated in the respective tables of the appendix.

4.3. Rec. 2020

With the Rec. 2020 color space, the HDR processor provides the most recent and largest television gamut, which has been standardized to date. As the name implies, this has been approved by the ITU standard ITU-R BT.2020 and has also found its place in the HDR standard BT.2100. Thus, HDR and Rec. 2020 are also considered a common combination in television production, which is why the HDR STATIC Constellation provides several useful presets covering common combinations. Please read more in chapter 5. "Presets".

Rec. 2020 spans a significantly larger color space than its predecessors Rec. 709 and Rec. 601 (see figure at the beginning of chapter 4. "Colorimetry / Gamut"). The standard allows all colors contained in its color triangle to be encoded, even if they are not yet fully representable on today's displays.

A conversion from Rec. 2020 to Rec. 709 corresponds to a down-conversion*, whereas a conversion from Rec. 709 to Rec. 2020 corresponds to an up-conversion. Conversions between cine gamuts (ACES, DCI-P3) or one of the proprietary gamuts of the camera manufacturers (Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut, BMD Film) to Rec. 2020 correspond to a cross-conversion.**

**Note: Since the Rec. 2020 color gamut is significantly larger than the Rec. 709 gamut, a Rec. 2020 input signal may contain color values outside the Rec. 709 gamut. In case of a down-conversion from Rec. 2020 to Rec. 709, these values need to be transferred from the wider Rec. 2020 gamut to the smaller Rec. 709 gamut. This can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate "Gamut Mapping" algorithm (see chapter 4.7. "Gamut Mapping").*
***Note: Since these color gamuts differ in size and color chart position, the input signal may contain color values outside the target gamut (outside Rec. 2020). In some rare cases, a simultaneous conversion of the transfer characteristic (e.g. an HDR cross-conversion) may cause values outside the*

target gamut as well. In case of cross-conversion to Rec. 2020, these values need to be transferred from the outside to the boundary or the inside of the Rec. 2020 target gamut. This can be done either by a simple “clipping” of the values or by a more elaborate and more appropriate “Gamut Mapping” algorithm (see chapter 4.7. “Gamut Mapping”).

However, it should be noted that a conversion between these cine gamuts or these proprietary color gamuts of the camera manufacturers and Rec. 2020 is only permissible in the direction from one of these gamuts *to* Rec. 2020, since these cine gamuts as well as the proprietary color gamuts of the camera manufacturers are only available on the input side as “Input Colorimetry” (see chapters 4. “Colorimetry / Gamut”, 4.4. “Cine Gamuts (DCI-P3, ACES)” and 4.5. “Manufacturers’ Gamuts”).

Basically, Rec. 2020 should be selected as "Input Colorimetry" whenever a Rec. 2020 color space signal is present on the input side, or as "Output Colorimetry" when a present signal is to be transferred to the Rec. 2020 color space. Thus, Rec. 2020 can be selected as both input and output colorimetry and can be used in combination with all transfer characteristics provided by the HDR STATIC Constellation. If Rec. 2020 is selected as both “Input Colorimetry” and “Output Colorimetry” simultaneously, the system will basically bypass the Rec. 2020 signal being present at the input.*

**Note: In some rare cases, a conversion of the transfer characteristic (e.g. an HDR cross-conversion) may cause values outside the target gamut, even if Rec. 2020 is selected as both “Input Colorimetry” and “Output Colorimetry”. These values outside the Rec. 2020 gamut can be transferred back to the inside of the gamut either by a simple “clipping” of the values or by a more elaborate and more appropriate “Gamut Mapping” algorithm (see chapter 4.7. “Gamut Mapping”).*

However, using Rec. 2020 color gamut in the HDR STATIC Constellation is allowed for HD and 4K/UHD footage only. Although the Rec. 2020 color space in BT.2020 has only been specified for 4K/UHD resolutions, the additional consideration of the color space in BT.2100 makes it equally valid for both HD and 4K/UHD resolutions. Therefore, using this color space in the HDR processor is allowed for both HD and 4K/UHD footage, but not for SD or 720p resolutions. A summary of these and all other restrictions, as well as all possible combinations, can be found in the tables of the appendix.

4.4. Cine Gamuts (DCI-P3, ACES)

With DCI-P3 and ACES, the HDR processor also provides color space standardizations from the field of digital cinema. The DCI-P3 standard, which refers to the actively used color space in digital cinemas, was defined by the digital-cinema community “Digital Cinema Initiatives” (DCI) and published in SMPTE RP 431-2. Approximating the color gamut of motion picture film, DCI-P3 is deployed in commercial digital cinema projectors. Furthermore, some LCD- and OLED-displays especially professional “grade 1” reference monitors also provide DCI-P3 as color gamut. Offering a larger color gamut than Rec. 709 but a smaller one than Rec.

2020, DCI-P3 could be used as an intermediate step in television systems and home cinemas as well. Currently, DCI-P3 content is limited to digital theaters and is not fully available to consumers.

The ACES ("Academy Color Encoding System") is an exchange format developed by AMPAS (Academy of Motion Pictures Arts & Sciences) or "Oscar Academy" for the reliable and consistent exchange of "film data". The system provides a free, open and device-independent color management and image exchange system for encoding digital film masters. ACES is suitable for acquisition, post-production, mastering and archiving. It also enables color transformations for consistent reproduction regardless of the display technology in use. The system is mainly published in SMPTE ST-2065-1 and supports both HDR and WCG. The ACES color space AP0 with its defined color primaries for red, green and blue covers all perceptible colors of the human visual system and thus includes all colors of the CIE chromaticity diagram. For this reason, ACES is in fact a "virtual" color space that cannot be displayed physically. The standard, with its 16-bit half float encoding, provides a total of 30 f-stops with 1024 "code words" per f-stop, creating an enormous headroom with almost unlimited dynamic range. For on-set use and transmission between camera systems, on-set look management systems and displays via SDI, the standard provides a lightweight integer encoding with ACESproxy (AP1) color space. However, the ACES color space contained in the HDR processor corresponds to the AP0 color space.

The cine gamuts DCI-P3 and ACES, which are often used for acquisition, post-production, mastering and archiving of material of scenic productions, are provided in the HDR STATIC Constellation to be able to convert this kind of material into common color spaces of broadcast standards. The HDR STATIC Constellation is not meant to output or generate these gamuts, which is why these gamuts are only available on the input side of the processor. This is also the reason why the system will not bypass such a color space if one of these gamuts is present at the input of the processor and the Output Colorimetry “Auto” is selected. Instead, the system will automatically perform a down-conversion to Rec. 709 (see chapter 4.6. “Auto”).*

In principle, DCI-P3 or ACES should be selected as "Input Colorimetry" respectively whenever a signal with one of these color spaces is present on the input side and needs to be converted to one of the broadcast gamuts (Rec. 709, Rec. 2020). A conversion from DCI-P3 or ACES to Rec. 709 corresponds to a down-conversion*, a conversion from DCI-P3 or ACES to Rec. 2020 to a cross-conversion (see chapter 4. “Colorimetry / Gamut”).**

*Note: *Since the cine gamuts are significantly larger than the Rec. 709 gamut, an input signal of such kind may contain color values outside the Rec. 709 gamut. In case of a down-conversion from one of these gamuts to Rec. 709, these values need to be transferred from the wider cine gamut to the smaller Rec. 709 gamut. This can be done either by a simple “clipping” of the values or by a more elaborate, more appropriate “Gamut Mapping” algorithm (see chapter 4.7. “Gamut Mapping”).*

***Note: Since these color gamuts differ in size and color chart position, the input signal may contain color values outside the target gamut (outside Rec. 2020). In some rare cases, a simultaneous conversion of the transfer characteristic (e.g. an HDR cross-conversion) may cause values outside the target gamut as well. In case of cross-conversion from one of these cine gamuts to Rec. 2020, these values need to be transferred from the outside to the boundary or the inside of the Rec. 2020 target gamut. This can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate "Gamut Mapping" algorithm (see chapter 4.7. "Gamut Mapping").*

The cine gamuts DCI-P3 and ACES can be used in combination with all transfer characteristics. However, using DCI-P3 or ACES in the HDR STATIC Constellation is allowed for HD and 4K/UHD footage only, not for SD or 720p resolutions. A summary of these and all other restrictions, as well as all possible combinations, can be found in the tables of the appendix.

4.5. Manufacturers' Gamuts

The HDR STATIC Constellation also supports common proprietary camera capture gamuts of camera manufacturers such as Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut and BMD Film. These proprietary camera capture gamuts are also intended for wider color gamut and even exceed the size of Rec. 2020 containing even more visible colors. Most of these gamuts are quite similar to each other, which is why the Sony S-Gamut is illustrated as an example in the CIE chromaticity diagram in chapter 4. "Colorimetry / Gamut".

Since these color spaces originate from the respective cameras and are therefore used for capturing only but not for displaying at all, they are only available as "Input Colorimetry". Therefore, only down-conversions from one of these proprietary gamuts to Rec. 709* or cross-conversions to Rec. 2020** can be performed, but no cross- or up-conversion to any of these gamuts. This is also the reason why the system will not bypass such a color space if one of these gamuts is present at the input of the processor and the Output Colorimetry "Auto" is selected. Instead, the system will automatically perform a down-conversion to Rec. 709 (see chapter 4.6. "Auto").*

**Note: Since the manufacturers' gamuts are significantly larger than the Rec. 709 gamut, an input signal of such kind may contain color values outside the Rec. 709 gamut. In case of a down-conversion from one of these gamuts to Rec. 709, these values need to be transferred from the wide gamut to the smaller Rec. 709 gamut. This can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate "Gamut Mapping" algorithm (see chapter 4.7. "Gamut Mapping").*
***Note: Since the manufacturers' gamuts and the Rec. 2020 gamut differ in size and color chart position, the input signal may contain color values outside the target gamut (outside Rec. 2020). In some rare cases, a simultaneous conversion of the transfer characteristic (e.g. an HDR cross-conversion) may cause values outside the target gamut as well. In case of cross-conversion from one of these manufacturers' gamuts to Rec. 2020, these values need to be transferred from the outside to the boundary or the inside of the Rec. 2020 target gamut. This can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate "Gamut Mapping" algorithm (see chapter 4.7. "Gamut Mapping").*

Basically, these gamuts should always be used as “Input Colorimetry” respectively if one of these gamuts is present at the input of the processor, e.g. by directly connecting a camera capturing with one of these gamuts. However, using one of these proprietary gamuts in the HDR STATIC Constellation is allowed for HD and 4K/UHD footage only, not for SD or 720p resolutions. A summary of these and all other restrictions, as well as all possible combinations, can be found in the tables of the appendix. Further information about these proprietary gamuts and their properties should be taken from the documentation of the respective manufacturers.

4.6. Auto

By selecting “Auto” as “Input Colorimetry” and/or “Output Colorimetry” it is possible to use the auto feature for setting the input and/or output color space automatically.

By activating "Auto" as “Input Colorimetry”, the HDR processor automatically selects the color space of the signal being present at the input of the processor. However, the presence of this information as ancillary data in the video stream, i.e. in the vertical blanking region as VANC (vertical ancillary data) of an SDI signal, is necessary for using this feature.* If the information regarding the used color space is not contained in the data stream of the signal, this feature should not be used.

**Note:* *Markings in the VANC are read and inserted by the processor according to ITU-R BT.1120-9 for HD and SMPTE - ST2082-10:2018 for 4K/UHD. These standards allow the markings of BT.709 and BT.2020 only!*

Using this setting as "Input Colorimetry" has the advantage that, regardless of which signal is present at the input, it is always ensured that the correct conversion is carried out if the desired output color gamut has been selected as "Output Colorimetry". Depending on which gamut is present at the input and which target gamut is selected at the output, either a down-conversion, a cross-conversion or no conversion of the gamut will be performed.**

***Note:* *The information about color space transformations given in chapter 4.7. “Gamut Mapping” and in the respective subchapters of the affected color gamuts must be considered.*

By selecting "Auto" as “Output Colorimetry”, the output color space is set according to the “Input Colorimetry”, assuming this output format corresponds to one of the standards supported by the HDR STATIC Constellation.*** An overview of all permissible and impermissible combinations can be found in the tables of the appendix. Therefore, by selecting “Auto” as Output Colorimetry, the color space of the input signal is basically bypassed (unless it is one of the cine gamuts or one of the proprietary manufacturers’ gamuts***), which means that no color space conversion will be performed.

****Note:* *As the proprietary color gamuts of the camera manufacturers as well as the cine gamuts are only available at the input of the processor, this feature is not available for these gamuts. If “Auto” is selected as Output Colorimetry and one of these gamuts is present at the input, the system will automatically perform a down-conversion to Rec. 709.*

Depending on which gamut is present and selected at the input, either a down-conversion or no conversion of the gamut will be performed if “Auto” is selected as Output Colorimetry.*

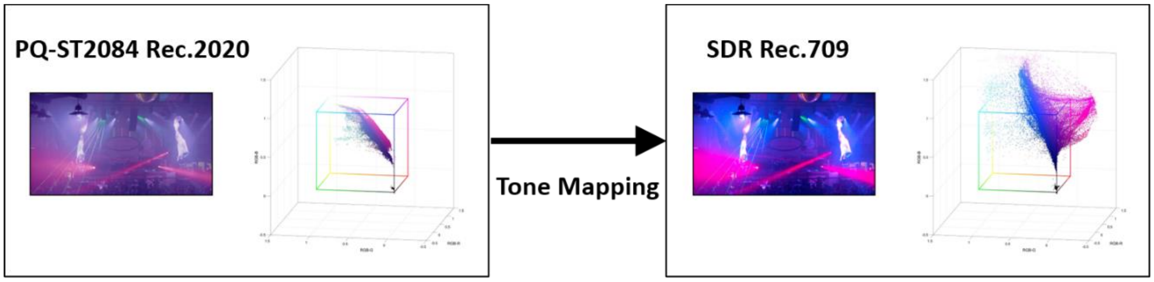
**Note:* *The information about color space transformations given in chapter 4.7. “Gamut Mapping” and in the respective subchapters of the affected color gamuts must be considered.*

By using “Auto” as both “Input Colorimetry” and “Output Colorimetry” simultaneously, the system will basically bypass the color gamut of the input signal unless it is one of the cine gamuts or one of the proprietary manufacturers’ gamuts.

Note: *The Operation Mode “bypass HDR/SDR” prevents conversions between color spaces in connection with HDR characteristics from being performed. In this mode, color space conversions are only performed correctly in connection with SDR (Gamma BT.709) signals. Moreover, this operation mode prevents up-, down- and cross-conversions of transfer characteristics from being performed (see chapter 2.1. “Operation Mode “bypass HDR/SDR””). When using Auto, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.*

4.7. Gamut Mapping

With the UHDTV gamut Rec. 2020, the cine gamuts DCI-P3 and ACES as well as the proprietary color gamuts of the camera manufacturers (Sony S-Gamut, Panasonic V-Gamut, Arri Alexa, RED Wide Gamut, Canon Cinema Gamut and BMD Film), a total of nine wide color gamuts can be processed by the HDR processor. Since these wide gamuts differ in size and position (in the CIE chromaticity diagram) and span a significantly larger color gamut than the HDTV gamut Rec. 709 (see chapter 4. “Colorimetry / Gamut”), material being captured with one of these gamuts may contain color values which may not be covered by the desired target gamut (e.g. by Rec. 709). Consequently, a tone mapping (in case of down-converting to Rec. 709) will result in color values lying outside the target gamut Rec. 709. The following figure shows an example of color values in the R’G’B’ cube model before and after a conversion from PQ-ST2084 Rec. 2020 to SDR (Gamma BT.709) Rec. 709 using a tone mapping operation. After the conversion is executed, some of the color values are clearly lying outside the (Rec. 709) R’G’B’ cube.

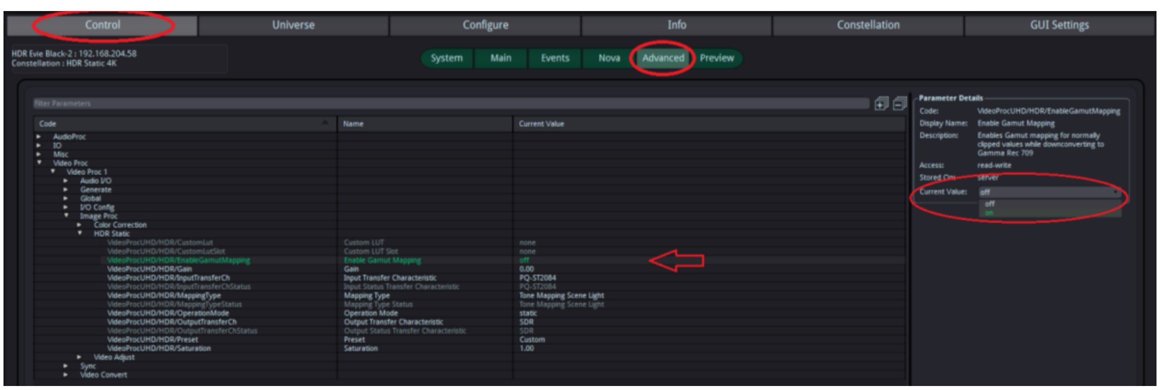


R'G'B' color values before and after conversion from PQ-ST2084 2020 to SDR 709

However, down-converting to Rec. 709 is not the only case in which color values outside the target gamut can be caused. Since the wide color gamuts differ in size and color chart position, a cross-conversion from one of these gamuts to Rec. 2020 can also result in values outside the Rec. 2020 target gamut. In some rare cases, a simultaneous conversion of the transfer characteristic (e.g. an HDR cross-conversion) may cause values outside the target gamut as well, even if *no* conversion of the gamut is performed!

To be able to process and display the values lying outside a certain target gamut (e.g. Rec. 709), these values need to be transferred to the boundary or the inside of the target gamut and thus to the boundary or the inside of the R'G'B' cube (see figure on the following page).

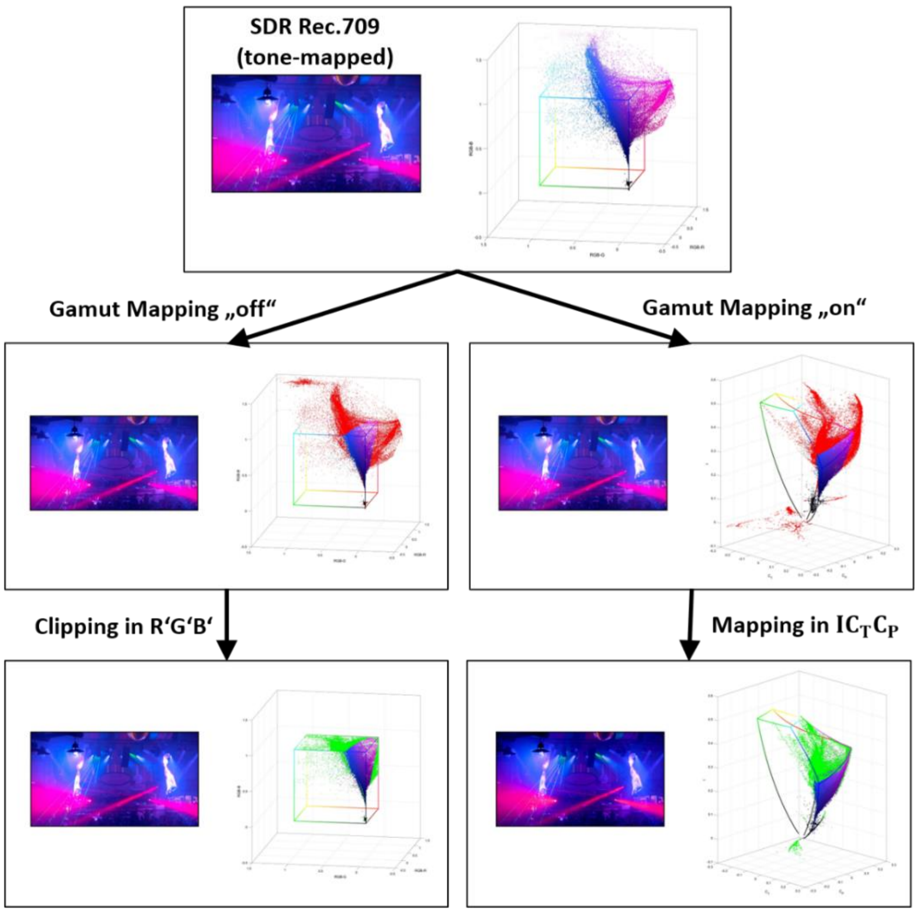
The HDR processor offers two possibilities to perform such a transformation of color values lying outside the target gamut. This can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate mapping of the values by a "Gamut Mapping" algorithm, which technically performs a color volume mapping.



Where and how to enable the "Gamut Mapping" in the greenGUI

The "Gamut Mapping" option can be found on the "Advanced" tab in the "Code" column under "Video Proc>Video Proc x>Image Proc>HDR Static>Enable Gamut Mapping" (see figure above). The mapping can be enabled by setting the "Current Value" to "on".

If the "Current Value" is set to "off", the "clipping" method is used instead. In this case, color values outside the target gamut will be simply moved to the edge of the gamut. This can either cause colors to be displayed vividly and highly saturated, or it causes colors to be displayed incorrectly or not to be displayed at all. As a result, hue changes and artefacts such as constant color regions (color block artefacts) may occur (see image samples on the last page of this chapter). The clipping method is performed in the R'G'B' color representation (see following figure), which is not very well suited for color space transformation due to the missing reference to the human visual system (HVS).



Clipping in R'G'B' vs. mapping in IC_TC_P

For a perceptually accurate reproduction of converted HDR images, the color space transformation should be performed by using the “Gamut Mapping”, which technically performs a color volume mapping. As shown in the figure above, the mapping is performed in the IC_TC_P color representation, which accurately represents the vision capabilities of the HVS. This is because IC_TC_P with its logarithmic scaling of the brightness axis allows the human perception of brightness (which in fact is logarithmic) to be considered. In addition, the decorrelation of the channels in IC_TC_P as color difference representation plays a decisive role for accurate color volume mapping. During mapping process, colors outside the target color space are allocated to colors in the target space in a perceptually accurate manner. This is done using a method called “PAHI” (= “Perception Accurate Hueshift Interpolating”) [1], in which necessary hueshifts are interpolated perceptually accurate. The PAHI method provides a solution for the mapping between color volumes with large size differences. Therefore, the “Gamut Mapping” option can preserve color differentiation in critical color areas. For more information about the entire mapping process, see [1].

[1] P. Kutschbach, “A Color-Volume Mapping System: For a perception-accurate reproduction of HDR Imagery in SDR production workflows”, SMPTE 2020 Game On

Clipping of the color values (left) vs. Mapping of the color values (right)

As can be seen in the image samples above, the “Gamut Mapping” allows more details to be preserved in critical image areas. Clipped areas are no longer clipped or less clipped than before and colors are displayed correctly according to the human color perception. But compared to clipping, the “Gamut Mapping” may produce a more desaturated result, especially in critical image areas. Therefore, clipping may provide a more saturated result, but mapping tends to be better suited for accurate color reproduction.

However, the “Gamut Mapping” operation is not roundtrip capable since there is no inverse operation for the “Gamut Mapping” existing. As a result, the image impression will change after “round-tripping” (e.g. from Rec. 2020 to Rec. 709 and back again to Rec. 2020), which may result in “round-tripped” material showing a difference in hue and saturation compared to the original version of the material.

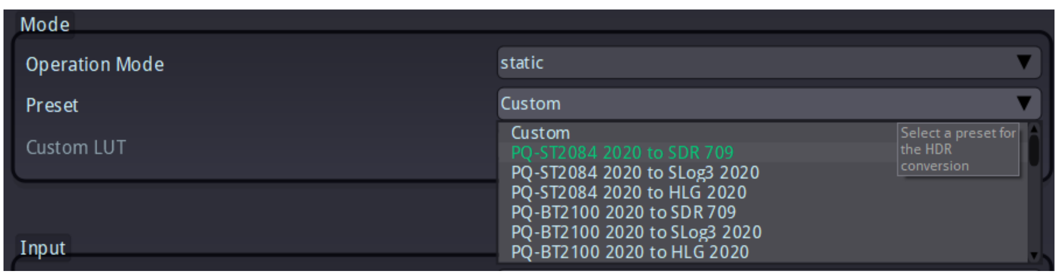
By combining Tone Mapping, which is able to perform a compression of large differences in the brightness range, and “Gamut Mapping”, which is able to perform a compression of large differences in the chromaticity range, the HDR processor is able to handle both, the compression of brightness and chromaticity. This combination of Tone Mapping and “Gamut Mapping” leads to the visual most pleasing results in most cases. However, in order to achieve the image impression that most closely matches the expectations, it is recommended to check from case to case which achieves the best result, gamut clipping or “Gamut Mapping”.

5. Presets

The HDR STATIC Constellation provides a number of useful presets that will make it easier and faster using the constellation. All conversions between transfer curves and color spaces can be selected with just a few mouse clicks. These presets include all conversions between common combinations of transfer characteristics and color gamuts, which result from the ITU broadcast production standards BT.709, BT.2020 and BT.2100.

As already described in chapter 4.3. "Rec. 2020", the combination of Rec. 2020 with an HDR transfer characteristic according to BT.2100 is a particularly common option since the Rec. 2020 color space is also an integral part of the HDR standard BT.2100. Therefore, PQ* and HLG in combination with Rec. 2020 color space are considered in the presets. The combination of the SDR characteristic (Gamma BT.709) and Rec. 709 color gamut, which is also considered to be the usual combination, is included in the presets as well. In addition to these combinations, presets including SLog3 as a widespread camera characteristic are also included. Thus, settings that are necessary for certain workflows can be made in no time.

**Note:* *Both PQ-ST2084 and PQ-BT2100 are considered in the presets in combination with Rec. 2020. When using a preset containing one of these transfer characteristics, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered.*



Selecting a Preset

All other conversion combinations that are not defined by these standards but still allowed in the HDR STATIC Constellation can be set by selecting "Custom"**, which can be found in the "Preset" drop-down list, too. Settings including the proprietary camera characteristic

***Note:* *The setting "Custom" does not necessarily have to be selected in the drop-down list before custom settings can be set. As soon as a setting is made which does not match any of the defined presets, the Custom setting will automatically be activated.*
Note: *The Operation Mode "bypass HDR/SDR" prevents up-, down- and cross-conversions of transfer characteristics from being performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In this mode, color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). When using Auto presets, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.*

and/or gamuts of the camera manufacturers as well as the cine gamuts DCI-P3 and ACES need to be selected manually by using the Custom setting as well.

The following table summarizes the available presets and categorizes them. The respective categories of the presets are discussed separately in the following chapters.

Presets		to			
		SDR BT.709	PQ* 2020	HLG 2020	SLog3 2020
from	SDR BT.709	non-existent	up	up	up
	PQ* 2020	down	non-existent	cross	cross
	HLG 2020	down	cross	non-existent	cross
	SLog3 2020	down	cross	cross	non-existent

Conversion overview of the available presets

5.1. Down-Conversion Presets

A down-conversion can be selected as a preset whenever one of the broadcast HDR signals according to the ITU (PQ**, HLG) or an SLog3 signal in combination with the Rec. 2020 color space is present at the input and needs to be converted to SDR (Gamma BT.709) in combination with Rec. 709 color space. Of course, the choice of the correct preset depends on the transfer characteristic being present at the input. The representatives that can occur in this case are therefore: PQ**, SLog3 or HLG, and must each occur in combination with the Rec. 2020 color space.

Down-Conversion		to
		SDR BT.709
from	PQ** 2020	down
	HLG 2020	down
	SLog3 2020	down

Overview of the presets available for down-conversion

***Note:** *Both PQ-ST2084 and PQ-BT2100 are considered in the presets in combination with Rec. 2020. When using a preset containing one of these transfer characteristics, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered. The cross-conversions from PQ-BT2100 2020 to PQ-ST2084 2020 and vice versa are not considered in the presets. These must be set manually by using the Custom setting.*
****Note:** *Both PQ-ST2084 and PQ-BT2100 are considered in the down-conversion presets. When using such a preset, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered.*

This conversion transfers the present HDR characteristic into the gamma characteristic and performs either a Direct Mapping or a Static Tone Mapping operation depending on the selected Mapping Type. By using the Tone Mapping operation, an improved picture quality can be displayed on an SDR display (see chapter 2.2.2. "Mapping" and 3.1.1. "Use cases of 'SDR'"). The transformation of the Rec. 2020 color gamut into the Rec. 709 gamut can be done either by a simple "clipping" of the values or by a more elaborate and more appropriate "Gamut Mapping" algorithm (see chapter 4.7. "Gamut Mapping").

Note: The Operation Mode "static" should be selected to properly execute these presets. If the Operation Mode "bypass HDR/SDR" is selected, no conversion of the transfer characteristic and consequently no mapping would be performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In "bypass HDR/SDR", color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). Therefore, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.

5.2. Up-Conversion Presets

An up-conversion can be selected as a preset whenever an SDR signal is present in combination with Rec. 709 color space at the input and needs to be converted into SLog3 or one of the broadcast HDR signals according to the ITU (PQ*, HLG) in combination with Rec. 2020 color gamut. The choice of the preset depends on the desired output characteristic. Depending on the workflow, the gamma characteristic of the SDR input signal can be converted to a PQ*, SLog3 or HLG characteristic. The Rec. 709 color space is transferred to the larger Rec. 2020 color space.

Up-Conversion		to		
		PQ* 2020	HLG 2020	SLog3 2020
from	SDR BT.709	up	up	up

Overview of the presets available for up-conversion

By applying one of these presets, a gamma characteristic is converted into one of the available HDR characteristics by using either a Direct Mapping or a Static Tone Mapping depending on the selected Mapping Type. While Direct Mapping preserves the appearance of the SDR content, the Tone Mapping operation automatically creates a stronger HDR look due to adjustment of luminance, which leads to a more brilliant image impression (see chapter 2.2.2. "Mapping" and 3.1.1. "Use cases of 'SDR'").

Note: The Operation Mode "static" should be selected to properly execute these presets. If the Operation Mode "bypass HDR/SDR" is selected, no conversion of the transfer characteristic and consequently no mapping would be performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In "bypass HDR/SDR", color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). Therefore, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.

**Note:* *Both PQ-ST2084 and PQ-BT2100 are considered in the up-conversion presets. When using such a preset, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered.*

5.3. Cross-Conversion Presets

A cross-conversion can be selected as a preset whenever one of the broadcast HDR signals according to the ITU (PQ*, HLG) or an SLog3 signal in combination with Rec. 2020 color space is present at the input and needs to be converted into another of these HDR transfer characteristics.

Using these presets does not perform color space transformation. The Rec. 2020 color space of the incoming signal remains untouched and is also present at the output.* In this case, the choice of the preset depends on both the incoming transfer characteristic and the desired output characteristic. The characteristic curves that in this case can occur at the input and can be created at the output are each: PQ**, SLog3 or HLG.

Cross-Conversion		to		
		PQ* 2020	HLG 2020	SLog3 2020
from	PQ* 2020	non-existent	cross	cross
	HLG 2020	cross	non-existent	cross
	SLog3 2020	cross	cross	non-existent

Overview of the presets available for cross-conversion

These presets only support Direct Mapping as Mapping Type since there is no need for a brightness correction by a tone mapping operation in this case. If Tone Mapping Scene Light or Tone Mapping Display Light is selected when using these presets, the Mapping Type will be forced to the respective Direct Mapping Type.

Note: *The Operation Mode "static" should be selected to properly execute these presets. If the Operation Mode "bypass HDR/SDR" is selected, no conversion of the transfer characteristic would be performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In "bypass HDR/SDR", color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). Therefore, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.*

**Note:* *Nevertheless, it may be suitable to use the "Gamut Mapping" algorithm since an HDR cross-conversion of the transfer characteristic may cause values outside the target gamut, even if no conversion of the gamut is performed (see chapter 4.7. "Gamut Mapping")*

***Note:* *Both PQ-ST2084 and PQ-BT2100 are considered in the cross-conversion presets. When using such a preset, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered. The cross-conversions from PQ-BT2100 2020 to PQ-ST2084 2020 and vice versa are not considered in the presets. These must be set manually by using the Custom setting.*

5.4. Auto Presets

By selecting one of the Auto Presets in the following table, the HDR STATIC Constellation ensures that the desired output signal is always generated, regardless of what signal is present at the input. Whether it is a down-, cross- or up-conversion depends on the present input signal.

However, to use these presets properly, the information about which signal is in fact present at the input is necessary as ancillary data in the video stream, i.e. in the vertical blanking region as VANC (vertical ancillary data) of an SDI signal.* If this information is not included in the data stream of the input signal used, the auto-preset should not be selected.

**Note:* *Markings in the VANC are read and inserted by the processor according to ITU-R BT.1120-9 for HD and SMPTE - ST2082-10:2018 for 4K/UHD. These standards allow the markings of BT.709 and BT.2020 in terms of colorimetry and SDR BT.709, HLG, PQ and "unspecified" in terms of transfer characteristics. "Unspecified" is regarded as SLog3 in the HDR processor.*

By using the "Auto to Auto" preset, the system will basically bypass the transfer characteristic and color gamut of the input signal, unless one of the proprietary manufacturer's characteristics or gamuts or one of the cine gamuts are present at the input of the processor. If such a characteristic and/or gamut is present at the input, the system will automatically perform a down-conversion to SDR (Gamma BT.709) and/or Rec. 709 instead (see chapter 3.3. "Auto" and 4.6. "Auto").** If one of the HDR characteristics PQ, HLG or SLog3 and/or the Rec. 709 or Rec. 2020 color gamut is present at the input, the system will basically bypass.** Therefore, no up-, down- or cross-conversion will be performed (see chapter 2.2.2. "Mapping" and 3.3. "Auto"). In addition, this feature still allows range conversions in combination with these HDR characteristics to be performed if the Operation Mode "static" is active (see chapter 2. "Operation Modes").

***Note:* *The information about color space transformations given in chapter 4.7. "Gamut Mapping" and in the respective subchapters of the affected color gamuts must be considered.*

Auto Presets		to			
		SDR BT.709	PQ*** 2020	HLG 2020	SLog3 2020
from	Auto	depending on input signal	depending on input signal	depending on input signal	depending on input signal

Overview of the available Auto presets

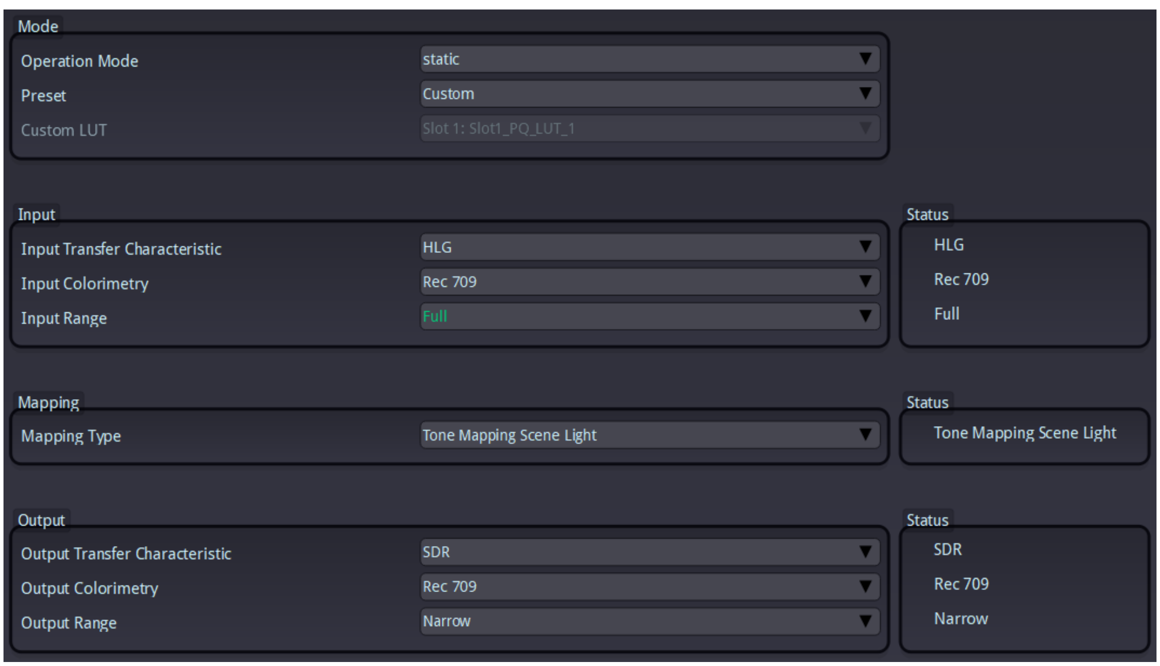
****Note:* *Both PQ-ST2084 and PQ-BT2100 are considered in the auto presets. When using a preset containing one of these transfer characteristics, the effects and capabilities resulting from these transfer characteristics as described in chapter 3.2.1. "PQ" must be considered.*

Note: *The Operation Mode "static" should be selected to properly execute the possible conversions resulting from these presets. If the Operation Mode "bypass HDR/SDR" is selected, no conversion of* *the transfer characteristic would be performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In "bypass HDR/SDR", color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). Therefore, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.*

5.5. Custom

The "Custom" setting, which can be found in the "Preset" drop-down list as well, allows combinations that are beyond the settings of the existing presets. As a result, less common combinations and conversions can also be set, which are not directly defined in the production standards BT.709, BT.2020 and BT.2100, but can theoretically occur. The user has the option to enforce these less common settings by using the Custom setting, as long as they are considered admissible in the HDR processor. An overview of all inadmissible combinations can be found in the "limitations" table of the appendix.

By using the Custom setting, the HDR STATIC Constellation allows, for example, the combination of an HDR signal (PQ-ST2084, PQ-BT2100, HLG. SLog3, etc.) with Rec. 709 color space, which is illustrated in the following figure.



Selecting Custom as Preset

The combination of an SDR signal (Gamma BT.709) with Rec. 2020 color space is also available by using the Custom setting.

Settings including the proprietary camera characteristics and/or gamuts of the camera manufacturers as well as the cine gamuts DCI-P3 and ACES need to be selected manually by using the "Custom" setting as well. As already mentioned in chapter 5.3. "Cross-Conversion Presets", conversions between PQ-ST2084 and PQ-BT2100 and vice versa must be selected as Custom setting, too.*

Note: The Operation Mode "static" should be selected in order to perform a conversion of the transfer characteristics. If the Operation Mode "bypass HDR/SDR" is selected, no conversion of the transfer characteristic and consequently no mapping would be performed. Conversion functionality of Colorimetry (color spaces) and Ranges in connection with HDR characteristics will not be performed either. In "bypass HDR/SDR", color space and range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals (see chapter 2.1. "Operation Mode "bypass HDR/SDR""). Therefore, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.

**Note: The setting "Custom" does not necessarily have to be selected in the drop-down list before custom settings can be set. As soon as a setting is made which does not match any of the defined presets, the Custom setting will automatically be activated.*

6. Signal Range

As already mentioned in chapter 3.1. "SDR (Gamma BT.709)" and 3.2. "HDR", the size of the available signal range depends on the quantization level of a characteristic curve. While an 8-bit range with $2^8 = 256$ code values is usually available for SDR reproduction, HDR with a quantization level of 10-bit even allows $2^{10} = 1024$ code values.* This corresponds to four times the number of available code values.

**Note: This statement refers in particular to the playback of SDR and HDR material. In the context of production, SDR is usually processed in 10-bit, too (in accordance with BT.601 and BT.709).*

However, most standards do not provide the complete range for encoding video signals. As already described in chapter 3. "Transfer Characteristics", the Transfer Characteristic determines how the brightness information is distributed over the available code value range. The "Range" parameter, which also exists in the HDR STATIC Constellation, decides how many or which values of the code value range are actually available or used for encoding the wanted signal, i.e. the video data.

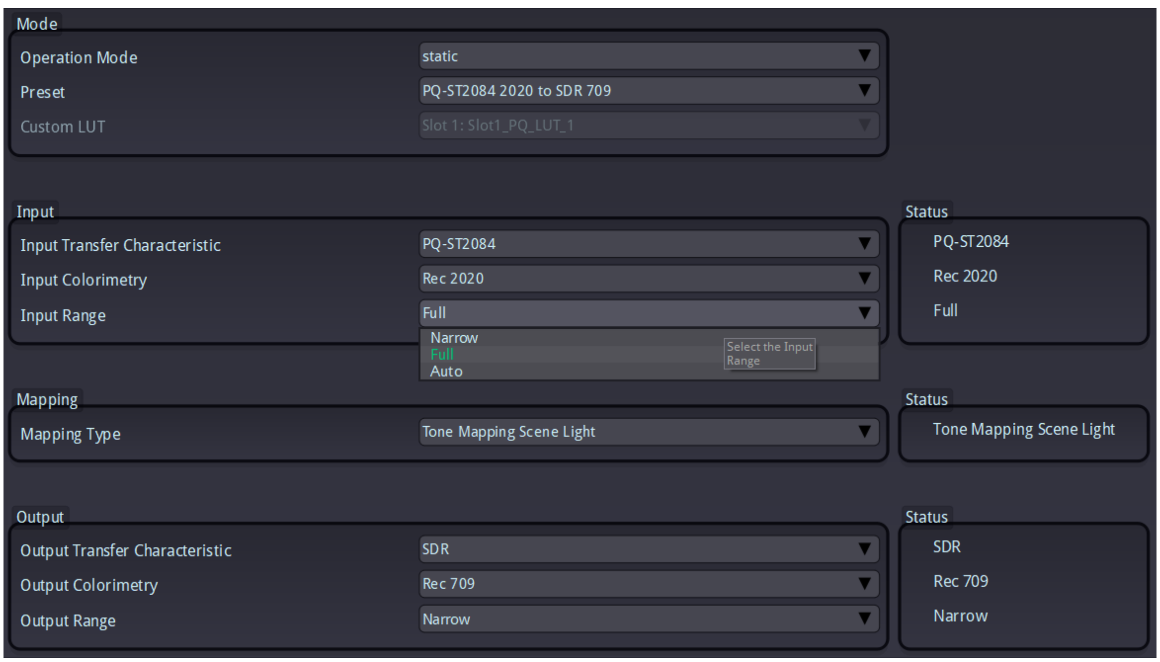
In the past, every broadcast standardization provided for a limited code-value range. During the introduction of digital television, the lowest and highest bits (code values) of the digital video signals have been reserved for encoding synchronization information. However, the code values required for this additional information are not available for encoding the actual video signal. Therefore, only a limited range of values remains for the actual video signal, which is why this type of signal range is called "narrow range". Narrow range signals are still in widespread use today and are considered the standard or default for encoding television signals. In addition, according to ITU Report BT.2408, there are two types of narrow range signals that must be considered today. Those that normally use 100% of the narrow range signal level and those that go beyond this level considering and allowing overshoots that extend above the nominal peak luminance into the so called “super-white” region (signal > 1.0) and under-shoots that extend below black into the so called “sub-black” region (signal < 0.0). This extended narrow range signal in fact uses 109% of nominal full scale. This topic is discussed in more detail in chapter 6.1. "Narrow Range".

Furthermore, the HDR standard ITU-R BT.2100 has newly introduced an additional range representation, called “full range”, providing a further definition of the signal range with the intention of being used only when all parties in broadcast agree. For the first time, this full range signal allows nearly** the entire signal range to be used for encoding a video signal. As a result, more intermediate values for a finer gradation of the brightness are available for encoding actual image information.

***Note: 10-bit: 4-1019 (inclusive)*

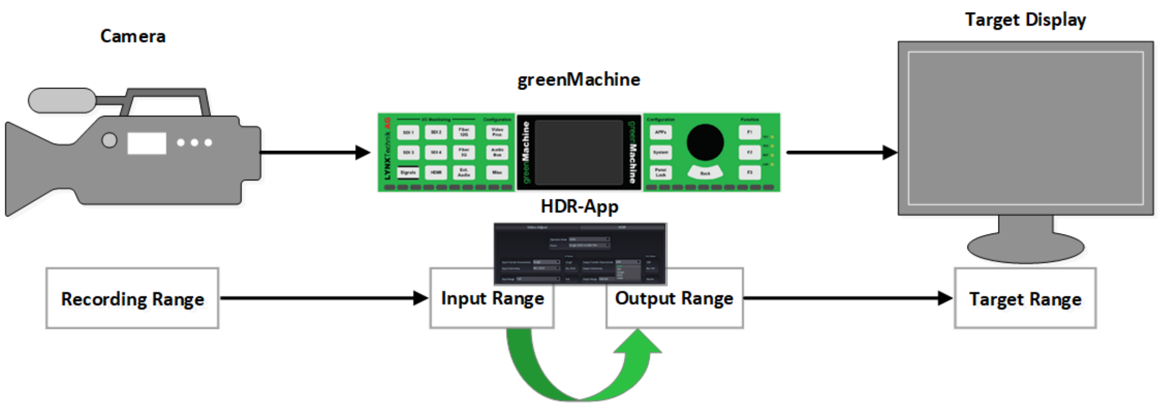
Consequently, the image impression differs between narrow and full range signals, which is why narrow range encoded image material should by no means be combined with full range encoded image material. Therefore, conversions between these ranges are of great importance. Especially by increasing amount of material used in both signal ranges, the range conversion becomes more and more important.

In addition to the conversions between transfer characteristics and color spaces, the HDR STATIC Constellation enables conversions between these signal ranges, including narrow-to-full range conversion, which corresponds to an up-conversion and full-to-narrow range conversion, which corresponds to a down-conversion. Whereas a conversion from narrow to full range results in the narrow code value range being "pulled apart" over the entire value range, the inverse conversion from full to narrow range basically results in a kind of compression of the full code value range into the limited range.



Selecting Input Range

The use of the range conversion should follow a simple principle: As the selection of the “Input Transfer Characteristic” or “Input Colorimetry”, the "Input Range" should also be selected according to the range of the input signal, while the "Output Range" should be selected according to the desired target range. If we stick to the camera example of chapter 3. "Transfer Characteristics" and 4. "Colorimetry / Gamut", operating an HDR camera directly in front of the greenMachine, the "Input Range" should be selected according to the used capture range of the camera (see figure below). Assuming the camera captures in full range, "Input Range" should also be selected as "Full". If a narrow range signal is required due to the workflow, a conversion from full to narrow range must be performed. So, the “Output Range” must be set to “Narrow” to do so (see figure above).



Operation example for ranges using the HDR processor

As described in chapter 2.1. "Operation Mode “bypass HDR/SDR””, signal range conversions of SDR (Gamma BT.709) signals are available in both Operation Modes "static" and "bypass HDR/SDR" since the conversion functionality for ranges is also available independently of the HDR STATIC Constellation in the greenMachine and thus remains untouched upon activation of the Operation Mode “bypass HDR/SDR”. If signal range conversions are to be performed in connection with HDR characteristics, the Operation Mode “static” must be selected (see chapter 2. “Operation Modes”). The available signal ranges are described in more detail below.

6.1. Narrow Range

In the past, every broadcast standardization provided for a limited code-value range. During the introduction of digital television, the lowest and highest bits (code values) of the digital video signals have been reserved for encoding synchronization information. However, the code values required for this additional information are not available for encoding the actual video signal. Therefore, only a limited range of values remains for the actual video signal, which is why this type of signal range is called "narrow range". Narrow range signals are still in widespread use today and are considered the standard or default for encoding television signals. The specification of the signal range “Narrow”, which is also unofficially known under the terms "legal range" or “limited range”, is basically included in all previously adopted broadcast standards, including ITU-R BT.601, BT.709, BT.2020 as well as BT.2100. However, under the term "narrow range" this specification appears for the first time in the HDR standard BT.2100, since this term simply did not exist before the adoption of the HDR standard.

The SDR standards BT.601 and BT.709 each include 8-bit quantization, providing a total of 2^8 = 256 code values or 10-bit quantization, providing a total of 2^{10} = 1024 code values for SD-SDR and HD-SDR signals. For encoding the actual image information, the narrow range specification of these two standards reserves the following code values:

- 16-235 → for 8-bit RGB signals
- 16-240 → for 8-bit color difference signals (Y CB CR)
- 64-940 → for 10-bit RGB signals
- 64-960 → for 10-bit color difference signals (Y CB CR)

The code values below and above are actually reserved for encoding timing reference signals or additional information:

- 0-15 and 236-255 → for 8-bit RGB signals
- 0-15 and 241-255 → for 8-bit color difference signals (Y CB CR)
- 0-63 and 941-1023 → for 10-bit RGB signals
- 0-63 and 961-1023 → for 10-bit color difference signals (Y CB CR)

The BT.2020 UHDTV standard, which does not yet provide a specification for HDR but is part of the HDR standard BT.2100, specifies a quantization of 10-bit, giving a total of 2^{10} = 1024 code values for encoding data. But even this standard only provides the narrow signal range as the default range, which limits the video coding range to the code values:

- 64-940 → for 10-bit RGB signals
- 64-960 → for 10-bit color difference signals (Y CB CR)

The values below and above are actually available for encoding additional data as well.

However, according to ITU Report BT.2408, there are two types of narrow range signals that must be considered today. In addition to the narrow range signal, which normally uses 100% of the narrow range signal level, there is another narrow range signal in fact using 109% of the video signal range available (i.e. of nominal full scale). This extended narrow range considers overshoots that extend above the nominal peak luminance into the so called "super-white" region (signal > 1.0) and under-shoots that extend below black into the so called "sub-black" region (signal < 0.0). The "super-white" and "sub-black" code value ranges are intended to accommodate signal transients and ringing in order to maintain signal fidelity after cascaded processing (e.g. filtering, video compression, etc.). Unless these signals (or signal regions) are not clipped (e.g. by using legacy equipment or full range signals), they may also be used to preserve additional highlights, e.g. after an HDR-to-SDR down-conversion. According to BT.2408 and BT.2250, the use of "sub-blacks" and "super-whites" in live SDR television productions, effectively increase the color gamut captured by the camera beyond the BT.709 color primaries as well. According to BT.2390, "the use of super-whites is much more advantageous for HLG than it is for SDR" (Gamma BT.709).

The HDR STATIC Constellation takes these signal range definitions into consideration and supports both narrow range signals with 100% and 109% signal level. By selecting "Narrow" as “Input Range” the HDR processor automatically detects whether a narrow range signal with 109% signal level is present at the input or not. If so, the processor is capable of passing the sub-blacks and super-whites of the signal by selecting “Narrow” as “Output Range” regardless of which conversion or whether a conversion is performed. Thus, these signals are not clipped in the HDR processor, which means that they can be used to obtain additional highlights, e.g. after HDR-to-SDR down-conversion.

The HDR standard BT.2100 also contains the narrow range specification from BT.2020, but newly introduced an additional "full range" representation providing a further definition of the signal range with the intention of being used only when all parties in broadcast agree. For the first time, this full range definition allows the entire signal range to be used for encoding the actual video signal, except the code values 0 to 3 and 1020 to 1023.

As a result, more intermediate values for a finer gradation of the brightness are available for encoding actual image information. Consequently, the image impression differs between narrow and full range signals, which is why narrow range encoded image material should by no means be combined with full range encoded image material. Therefore, conversions between these ranges are of great importance.

The HDR STATIC Constellation enables conversions between these signal ranges, including narrow-to-full range* conversion, which corresponds to an “up-conversion” and full-to-narrow range conversion, which corresponds to a “down-conversion”. Whereas a conversion from narrow to full range results in the narrow code value range being "pulled apart" over the entire value range, the inverse conversion from full to narrow range basically results in a kind of compression of the full code value range into the limited range.

**Note:* *By using full range signals, over- and under-shoots in the super-white and sub-black areas of an 109% narrow range signal would be clipped. So, a narrow-to-full range conversion would lead to clipping of the sub-black and super-white regions in case of an 109% narrow range signal being present at the input of the processor. If details that are critical to the artistic rendition of an image are placed in these areas, using full signal range should be avoided due to clipping of these details.*

The narrow range specification is available in the HDR processor for all formats and standards. Basically the “Input Range” should always be selected as “Narrow” whenever a narrow range signal is present at the input, while the “Output Range” should be selected as “Narrow” whenever a narrow range signal is required as target range.

According to BT.2408, the use of narrow range signals is strongly preferred for HLG to maintain signal fidelity and to reduce the risk of confusing full range with narrow range signals (and vice versa) in production.

6.2. Full Range

The HDR standard ITU-R BT.2100 providing a total of $2^{10} = 1024$ code values for 10-bit quantization has newly introduced an additional range representation, called “full range”, providing a further definition of the signal range with the intention of being used only when all parties in broadcast agree. For the first time, this full range signal allows nearly the entire signal range (code values) to be used for encoding the actual image information of the video signal, except the code values:

- 0-3 and 1020-1023 → in terms of 10-bit signals

As a result, more intermediate values for a finer gradation of the brightness are available for encoding actual image information. Consequently, the image impression differs between full and narrow range signals, which is why full range encoded image material should by no means be combined with narrow range encoded image material. Therefore, conversions between these ranges are of great importance. Especially by increasing amount of material used in both signal ranges, the range conversion becomes more and more important.

The HDR STATIC Constellation enables conversion functionality between full and narrow range signals, including full-to-narrow range conversion, which corresponds to a “down-conversion” and narrow-to-full range* conversion, which corresponds to an “up-conversion”. Whereas a conversion from narrow to full range results in the narrow code value range being "pulled apart" over the entire value range, the inverse conversion from full to narrow range basically results in a kind of compression of the full code value range into the limited range.

***Note:** *By using full range signals, over- and under-shoots in the super-white and sub-black areas of an 109% narrow range signal would be clipped. So, a narrow-to-full range conversion would lead to clipping of the sub-black and super-white regions in case of an 109% narrow range signal being present at the input of the processor. If details that are critical to the artistic rendition of an image are placed in these areas, using full signal range should be avoided due to clipping of these details.*

Since full range has only been specified in BT.2100, this range is only defined for HDR signals in the Rec. 2020 color space. In the HDR STATIC Constellation, using full range in combination with an SDR characteristic (Gamma BT.709) and the color space Rec. 709 is nevertheless allowed. The use of full range in combination with the proprietary characteristics and gamuts of the camera manufacturers as well as the cine gamuts as common combinations is also available in the HDR processor. Therefore, full range can be used in combination with all included transfer characteristics and color spaces.

Only the resolution of the used signal must comply with the BT.2100 standard, i.e. an HD or 4K/UHD resolution, in order to make use of the full range in the HDR processor. Signals with SD or 720p resolution in combination with full range are therefore considered inadmissible.

An overview of all applicable restrictions and conditions can be found in the tables of the appendix.

Basically the “Input Range” should always be selected as “Full” whenever a full range signal is present at the input, while the “Output Range” should be selected as “Full” whenever a full range signal is required as target range.

According to ITU Report BT.2408, the use of full range is useful for PQ signals providing an incremental advantage against the visibility of banding/contouring and in terms of processing. Since the range of PQ signals is as large as it is, it is rare for content to contain pixel values close to the extreme values of the range. Therefore, over- and under-shoots are unlikely to be clipped.

6.3. Auto Range

By selecting "Auto" as “Input Range” and/or “Output Range” it is possible to use the auto feature for setting the input and/or output range automatically. By activating “Auto” as "Input Range", the HDR processor automatically selects the range of the signal being present at the input. However, the presence of this information as ancillary data in the video stream, i.e. in the vertical blanking region as VANC (vertical ancillary data) of an SDI signal, is necessary for using this feature.* If the information regarding the used range is not contained in the data stream of the signal, this feature should not be used.

***Note:** *Markings in the VANC are read and inserted by the processor according to ITU-R BT.1120-9 for HD and SMPTE - ST2082-10:2018 for 4K/UHD. These standards allow the markings of both narrow and full range signals.*

Using “Auto” as "Input Range" has the advantage that, regardless of which signal is present at the input, it is always ensured that the correct conversion is carried out if the desired "Output Range" has been selected. By selecting "Auto" as “Output Range”, the output range is set according to the “Input Range”, assuming this output format corresponds to one of the standards supported by the HDR STATIC Constellation. An overview of all permissible and impermissible combinations can be found in the tables of the appendix. By using “Auto” as both “Input Range” and “Output Range” simultaneously, the system will basically bypass the signal range of the input signal.

Note: *The Operation Mode “bypass HDR/SDR” prevents conversions between signal ranges in connection with HDR characteristics from being performed. In this mode, range conversions are only performed correctly in connection with SDR (Gamma BT.709) signals. Moreover, this operation mode prevents up-, down- and cross-conversions of transfer characteristics from being performed. When using Auto, attention should be paid to which signal is present at the input and which Operation Mode and settings are selected to ensure the correct operation will be performed.*

7. Custom LUT

The Custom LUT feature provides 20 slots for uploading the user custom LUTs. Users will be able to add, delete and export LUTs using the graphical user interface called greenGUI

7.1. Supported File Formats

The greenMachine HDR Static Custom LUT supports the following format for importing and exporting single or multiple LUTs:

File Format	Description
.cube	A cube file is a text file that defines the look-up table. HDR Static uses a 3-dimensional table with the sample points of 33x33x33. If a user wants to import just one LUT on the greenMachine, then the user can choose any 33-point .cube 3-D LUT file.
.xml	The .xml file is an internal LYNX LUT Import and export file that carries the following information: Multiple LUT information (can hold a maximum of 20 LUTs information) Parameter settings for each LUT A user can make use of the .xml file to import and export multiple LUTs on a greenMachine. The imported and exported .xml file carries the following information related to each LUT: Input and output Colorimetry Input and output Range Input and output Transfer characteristics

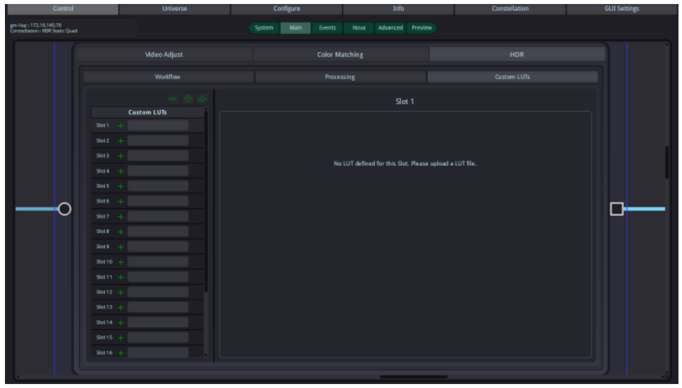
7.2. Uploading Custom LUTs

The HDR Static constellation consists of 20 slots for uploading user custom Luts. Each slot allows storage of one User Custom LUT. Any other LUT file format needs to be converted to ".cube" before uploading it on the greenMachine.

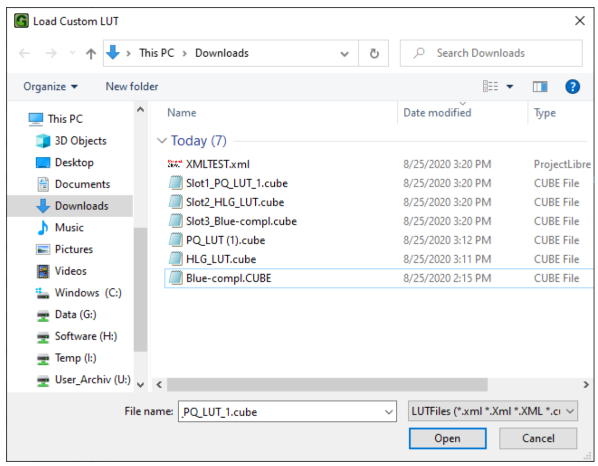
7.2.1. Importing a Single Custom LUT

To add a custom LUT on the greenMachine HDR Static, follow the below steps:

Step 1: Go to **Control** > **Main** > **Video**> **Image Proc** > **Custom LUTs**, the following window will appear:

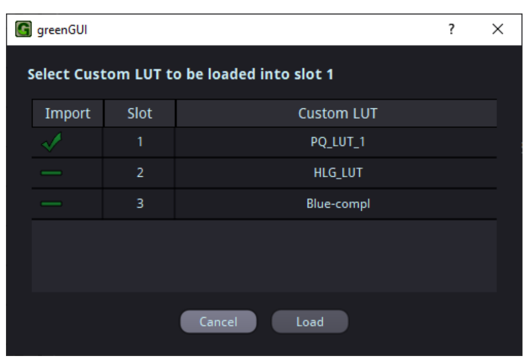


Step 2: Click on icon corresponding to the slot where the custom LUT is desired. A dialogue box appears for the file selection, as shown below:



Step 3: Select the ".cube" or ".xml" file for the upload.

Note: A .xml file (previously exported from a greenMachine HDR Static) may consist of multiple custom LUTs. When a user selects a .xml file for adding a custom LUT, a dialogue box will appear that allows the user to select the desired user LUT from a list. Only one custom LUT can be selected at a time in this process. The dialogue box is as shown below:



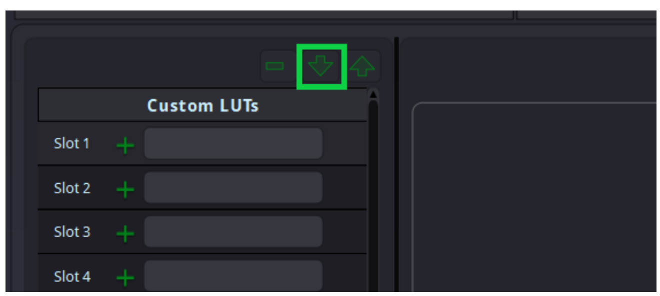
Step 4: On successful import of a custom LUT, the selected slot will display the uploaded custom LUT as highlighted below:

A user can edit the uploaded LUT name by clicking on the Textbox. The maximum allowed characters for the LUT name is 20.

7.2.2.Importing Multiple Custom LUT

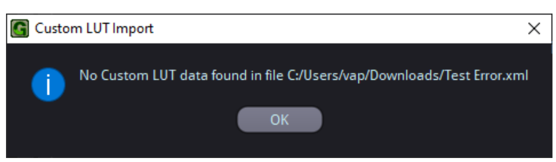
A user can import multiple LUTs by following the below steps:

Step 1: On the **Control** > **Main** > **Video**> **Image Proc** > **HDR** > **Custom LUTs** page, click on the  as highlighted below:



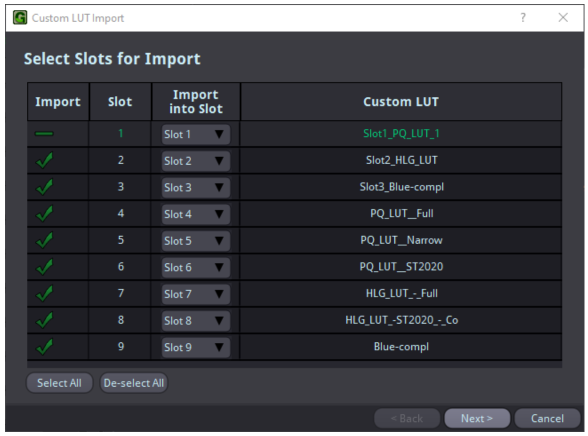
Step 2: On the opened dialogue box for file selection, select the .xml file for upload

Note: The .xml file should be a Lynx User custom LUT file previously exported from an HDR Static greenMachine. Any other file will give an error, as shown below:



To understand how to export custom LUT in .xml file format, check Section 3.5 of this document.

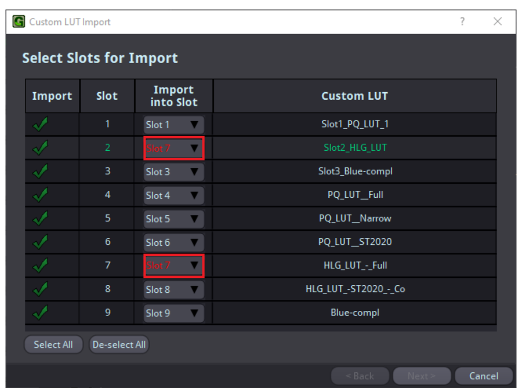
Step 3: A dialogue box is displayed that lists all the Custom LUTs along with their slot number present on the imported .xml file.



A user can select all the LUTs or may choose to pick only those LUTs that the user wants to import. All the LUTs with the icon  will not be imported.

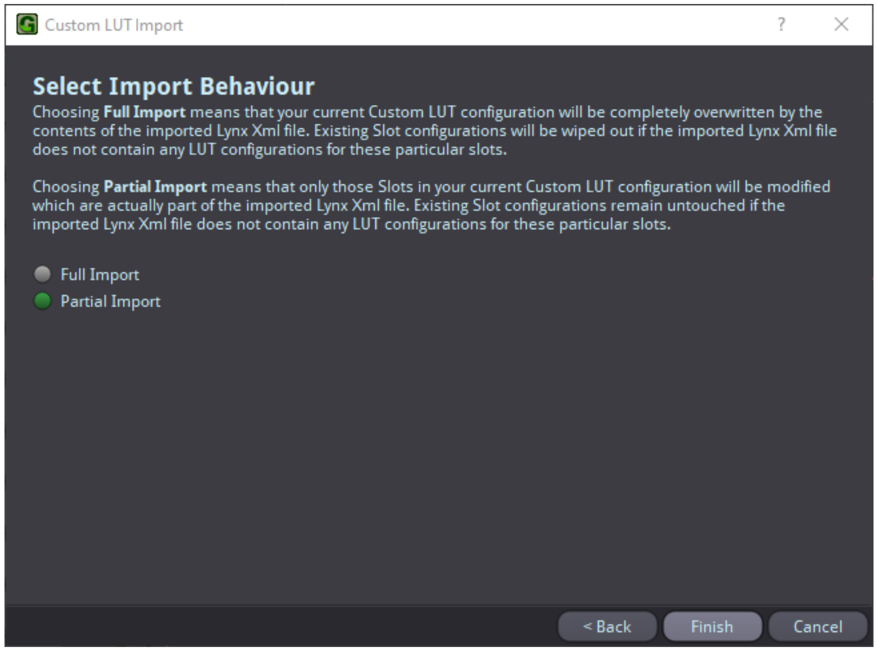
A user can also select the slot number on which the user wants to upload the LUT by choosing the slot from the column "Import into Slot."

Note: The chosen slot number must be unique within the LUTs slot listed on the .xml file. Any repeating slot number will be highlighted in red, as shown below:



Please note that any existing LUT on the selected slot number in greenMachine will be overwritten when a LUT is imported on the same slot.

Step 4: Click **Next** and the following "**Select Import Behaviour"** dialogue box is displayed



The following table provides a description of the options

Option	Description
Full Import	Select this option when all the existing LUTs on the greenMachine need to be wiped off entirely and updated with newly selected LUTs present on the LUT file.
Partial Import	Select this option when only the selected slots on the LUT file need to be imported. Any existing LUTs on these slots will be overwritten. The remaining slots will be untouched.

Step 5: Click **Finish** to import and complete the import process.

Note: The custom LUT files cannot be uploaded using the greenMachine front panel controls, and additional settings (In and out transfer characteristics, In and Out Range, and In and out color space) are only available on the greenGUI.

7.2.3. Configuring Custom LUTs

A custom LUT requires configuration of the input and output colour space, range, and transfer characteristics. These settings are required for all the uploaded LUTs.
The following table provides information related to the Input and Output settings of the LUT file:

Inpu	Input Transfer Characteristics	SDR	This information is only required for the input status displayed on the **Control** > **Main** > **Image Proc** > **HDR** > **Workflow**
		HLG	

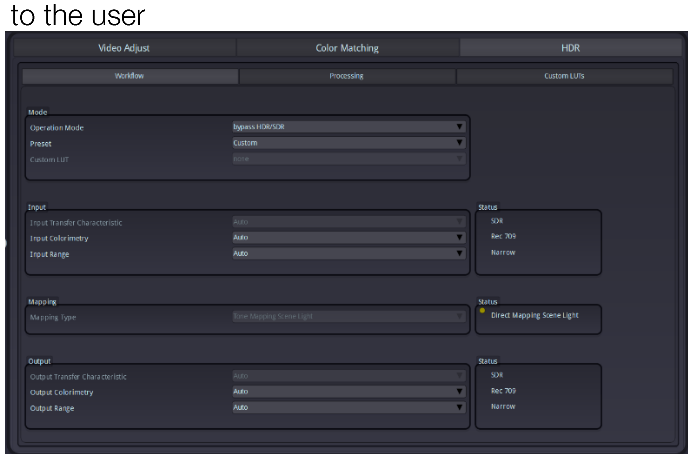
		PQ	page. There is no conversion or processing of any sort.
		Unspecified	
	Input colorimetry	Rec 601	The input colorimeter must be selected correctly to avoid incorrect output. This information will be displayed in the input status on the **Control** > **Main** > **Image Proc** > **HDR** > **Workflow** page.
		Rec 709	
		Rec 2020	
	Input Range	No Conversion	This setting allows the preservation of overs/under (Sub black and Super White) in the input signal.
		Auto to Full	In this setting, the range information is automatically fetched from the SDI VPID and converted to the FULL range. Note: *In case the SDI range detected in VPID is FULL, there will be no conversion.*
		Auto to Narrow	In this mode, the range information is automatically fetched from the SDI VPID and converted to the Narrow range. Note: *In case the SDI range detected in VPID is Narrow, there will be no conversion.*
		Narrow to Full	In this mode, an SDI Narrow range is converted Full range. Note: *In case the SDI input range is entered incorrectly, the output result will be wrong.*
		Full to Narrow	In this mode, an SDI Full range is converted Narrow range. Note: *In case the SDI input range is entered incorrectly, the output results will be wrong*
Output	Output Transfer Characteristics	SDR	This information is required for the SDI output VPID updates and output status displayed on the **Control** > **Main** > **Image Proc** > **HDR** > **Workflow** page. There is no conversion or processing of any sort.
		HLG	
		PQ	
		Unspecified	
	Output colorimetry	Rec 601	The output colorimeter must be selected correctly to avoid incorrect output VPID information. This information will be displayed in the output status on the
		Rec 709	

		Rec 2020	**Control** > **Main** > **Image Proc** > **HDR** > **Workflow** page.
	Output Range	No Conversion	In this setting, there will be no conversion in the output range.
		Follow Input	In this setting, the output range will be the same as the input range configuration.
		Narrow to Full	In this setting, the output range will be converted from Narrow to Full
		Full to Narrow	In this setting, the output range will be converted from Full to Narrow

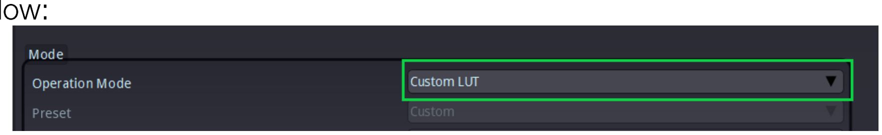
7.2.4.Deploying Custom LUTs

A user can deploy custom LUT on an HDR Static greenMachine by following the below steps:

Step 1: Go to **Control** > **Main** > **Image Proc** > **HDR** > **Workflow,** the following page is displayed to the user



Step 2: In the **Operation Mode** drop-down list, select **Custom LUT** as highlighted below:



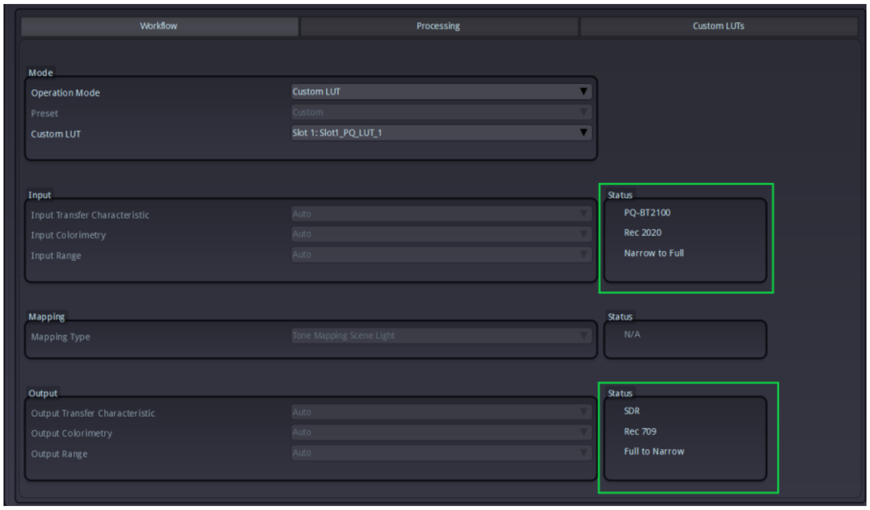
Step 3: In the **Custom LUT** drop-down list, select the desired slot or LUT to be deployed. Once the LUT is selected, this LUT will be deployed.

Note: When a user selects **None** option, then a unity LUT is applied that bypasses the input signal without any processing to the output.

A user can check the Input and Output preview on the **Control** > **Preview** option.

7.2.5. Viewing Custom LUT status

A user can check the input and output status of a deployed Custom LUT on the **Control** > **Main** > **Image Proc** > **HDR** > **Workflow page.** The status of the deployed custom LUT can be seen on the Workflow page as highlighted below:

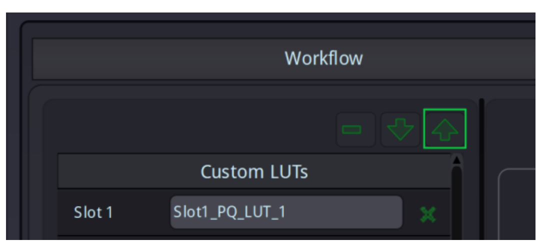


7.2.6. Exporting Custom LUT

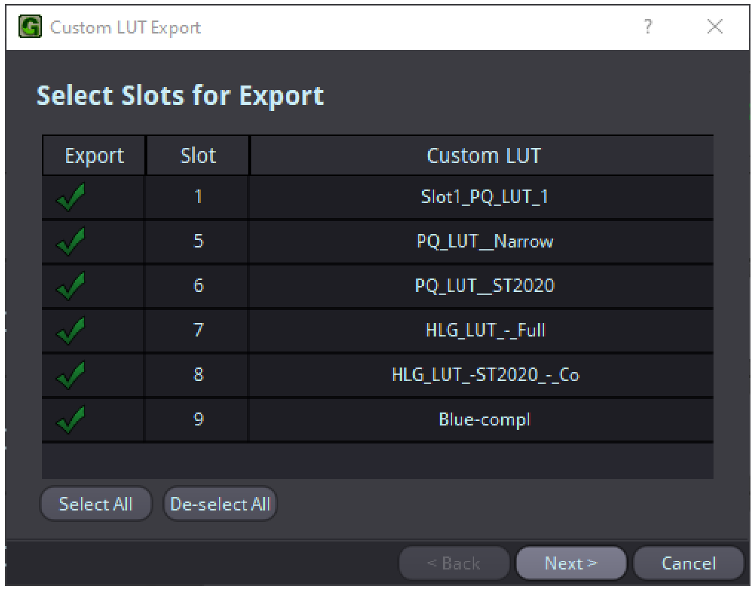
A user can export the Custom LUT on each slot either in .cube format or into Lynx internal .xml format. The .cube format represents one user custom LUT while a .xml file may consist of multiple or a maximum of 20 LUTs. A user can export Custom LUTs from a greenMachine by following the below steps:

Step 1: Go to **Control** > **Main** > **Image Proc** > **HDR** > **Custom LUTs**

Step 2: Click on the  as highlighted below:



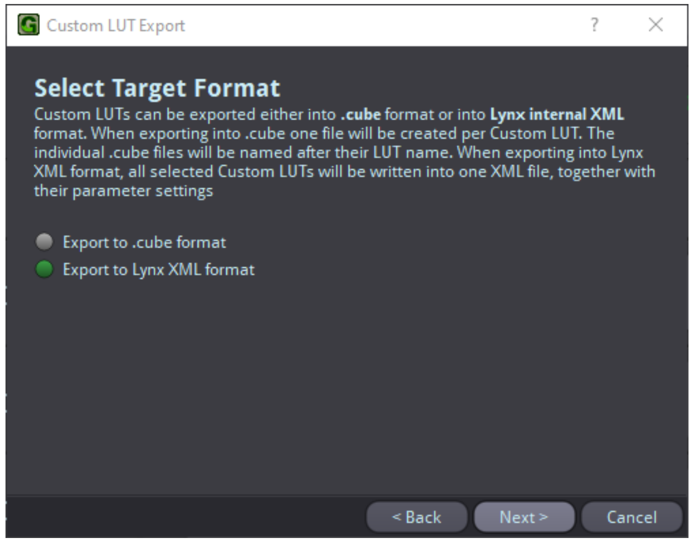
A dialogue box appears on the screens, as shown below:



Step 3: The dialogue box will list all the Custom LUTs present on the slots. Empty slots will not be displayed in the list. A user can select all the LUTs that need to be exported or can deselect LUTs that do not require an export. An ▬ icon corresponding to a LUT Slot would indicate that this LUT will not be exported. All the remaining LUTs with ✓ icon will be exported.

A user can also decide to select all the LUTs by clicking on the button "**Select ALL**" or may choose to deselect all by clicking on the button "**De-Select.**"

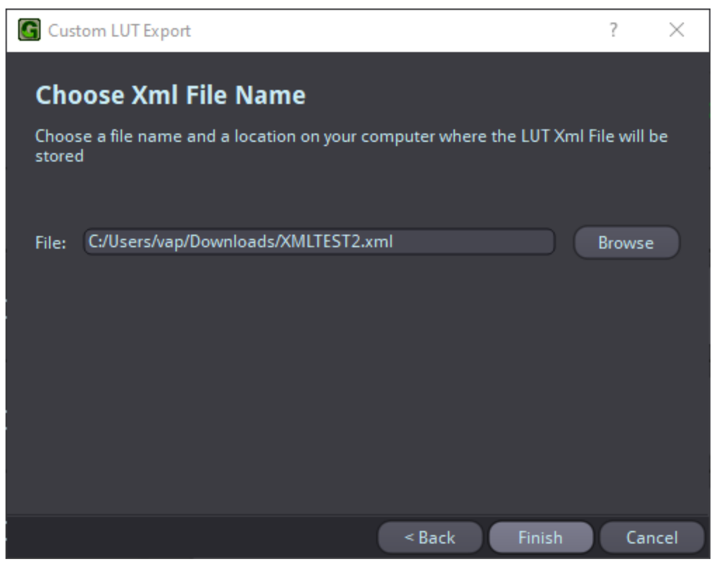
Step 4: Click **Next** and the following dialogue box with options are displayed:



Step 5: Click on "**Export to .cube format**" to export individual LUT file for all the selected LUT slots.

Click on "**Export to Lynx XML format**" to export all the selected LUT files into a single file in .xml format. This .xml file can be imported on other greenMachine to import up to 20 Custom LUTs.

Step 6: Click **Next** and the following dialogue box is displayed to the user



Step 7: For **.cube** file export, enter the location of the file, and for **.xml** file export, enter the exported file name and location.

Step 8: Click **Finish** to complete the export process

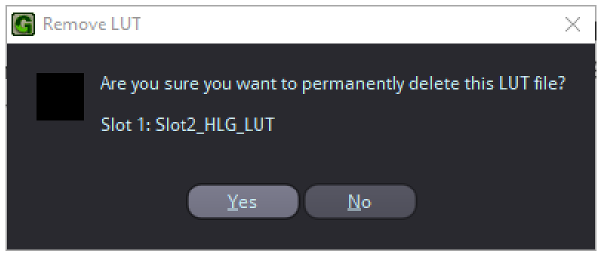
7.2.7.Deleting Custom LUT

7.2.7.1 Deleting a single Custom LUT on a slot

A user can delete a Custom LUT on a slot by following the below steps:

Step 1: Go to **Control** > **Main** > **Image Proc** > **HDR** > **Custom LUTs**

Step 2: Click on the icon  corresponding to the Slot /LUT that requires deletion. A warning dialogue box to verify the selected LUT deletion will appear as shown below:



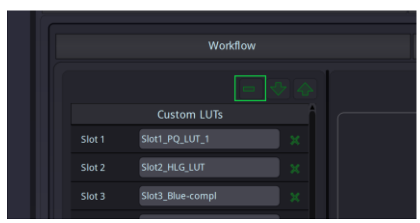
Step 3: Click **Yes** to confirm the deletion.

7.2.7.2 Deleting a single Custom LUT on a slot

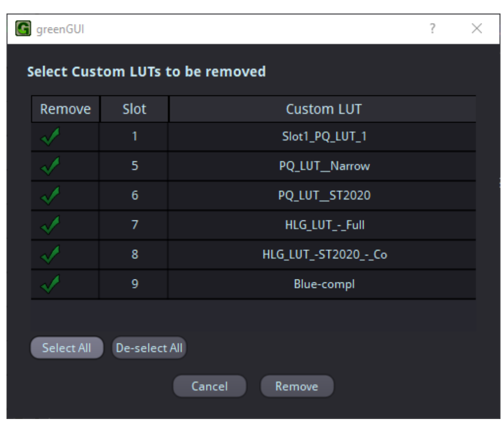
A user can delete all or multiple Custom LUT by following the below steps:

Step 1: Go to **Control** > **Main** > **Image Proc** > **HDR** > **Custom LUTs**

Step 2: Click on  icon as highlighted below:

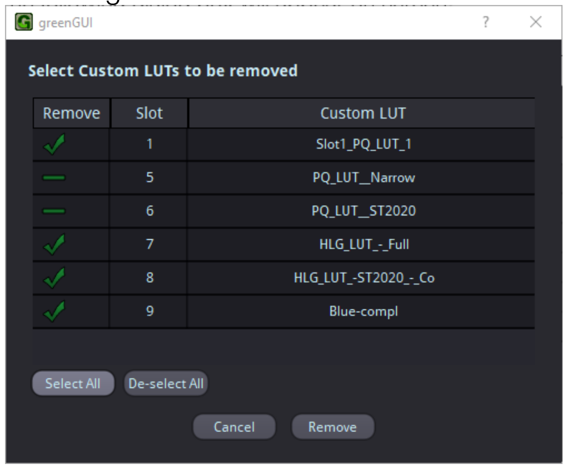


The following dialogue box will appear on the screen:



Step 3: The dialogue box will list all the Custom LUTs present on the slots. Empty slots will not be displayed in the list. A user can select all the LUTs that need to be deleted or can deselect LUTs that do not require a deletion. An 

icon corresponding to a LUT Slot would indicate that this LUT will not be deleted. All the remaining LUTs with icon will be deleted.

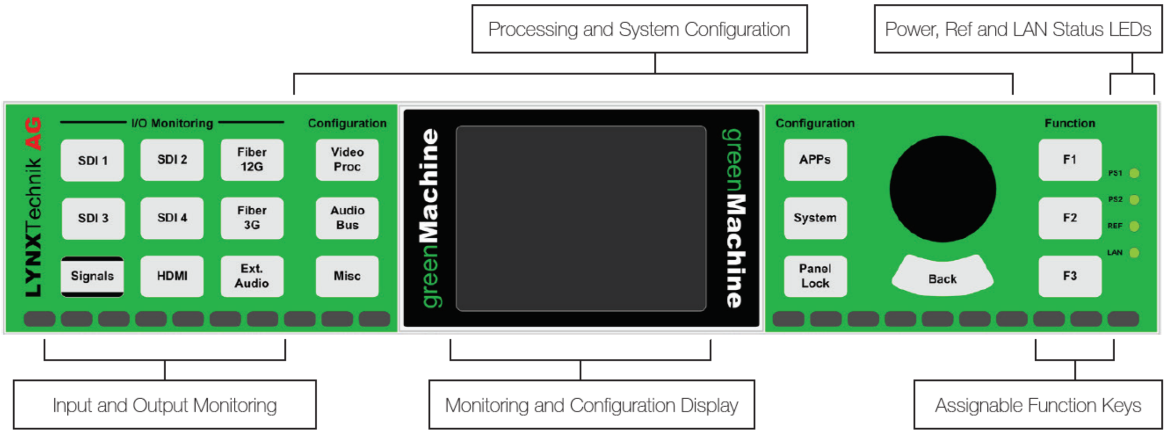


A user can also decide to select all the LUTs by clicking on the button "**Select ALL**" or may choose to deselect all by clicking on the button "**De-Select.**"

Click "**Remove**" to delete or "**Cancel**" to cancel the deletion process.

8. Local Control

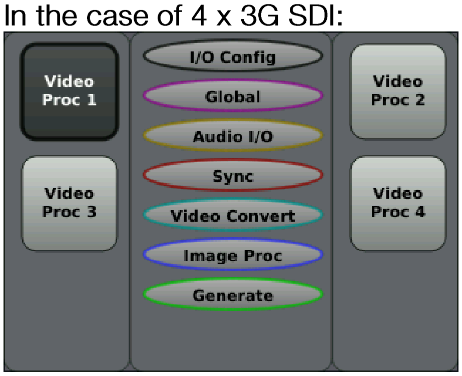
The HDR STATIC Constellation can also be controlled from the local control panel.



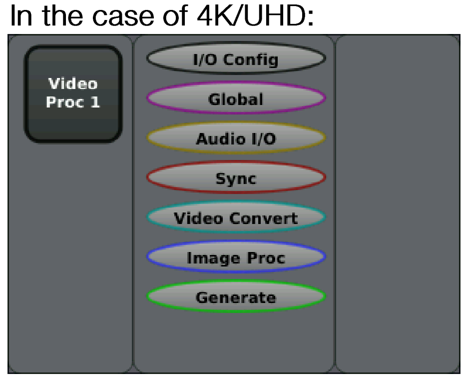
For more information on how to use the local control panel please read the greenMachine titan manual, which is available on the LYNX website: www.lynx-technik.com

To get access to the control parameters of the HDR STATIC Constellation please press the button "Video Proc" next top left of the display. The following menu will show up.

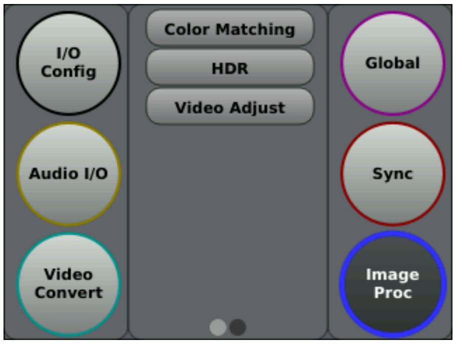
In the case of 4 x 3G SDI:

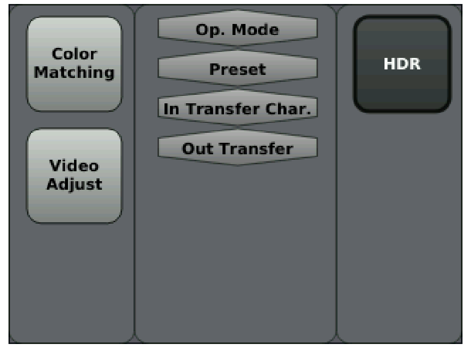


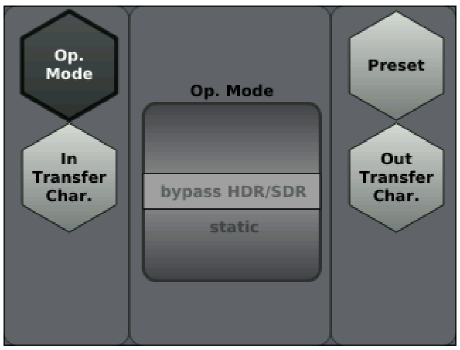
In the case of 4K/UHD:



Then select the processing channel you would like to adjust, and the following menu will be displayed, then select "Image Proc" and in the next menu "HDR"



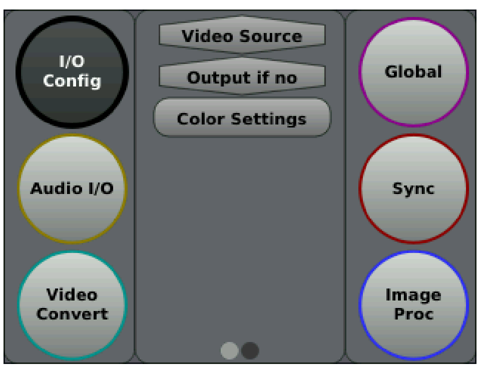


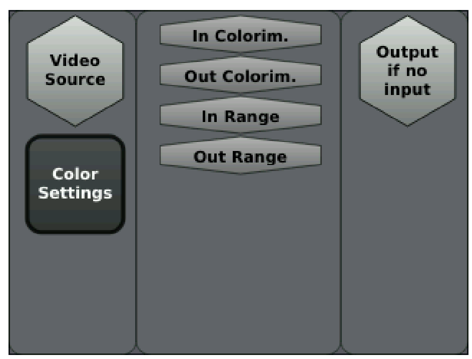


In this menu you can set/select the specific parameters of the HDR STATIC Constellation:

- Operation Mode
- Input Transfer Characteristic
- Output Transfer Characteristic
- Presets

For general color settings select "I/O config" in the main menu of the selected channel and then select color settings.





In this menu you can set/select the following parameters:

- Input Color Space (In Colorim.)
- Output Color Space (Out Colorim.)
- Input Range
- Output Range

9. Appendix

Format Limitations designated as "invalid" and shown in red:

Format Limitations		Formats			
		SD	720p	HD	4K/UHD
Transfer Characteristic	SDR	valid	valid	valid	valid
	PQ	invalid	invalid	valid	valid
	HLG	invalid	invalid	valid	valid
	SLog3	invalid	invalid	valid	valid
	Manufacturers' characteristics	invalid	invalid	valid	valid
Colorimetry	Rec. 601	valid	invalid	invalid	invalid
	Rec. 709	invalid	valid	valid	valid
	Rec. 2020	invalid	invalid	valid	valid
	Cine Gamuts (DCI-P3, ACES)	invalid	invalid	valid	valid
	Manufacturers' Gamuts	invalid	invalid	valid	valid
Range	Narrow	valid	valid	valid	valid
	Full	invalid	invalid	valid	valid

Colorimetry Limitations designated as "invalid" and shown in red:

Colorimetry Limitations		Colorimetry				
		Rec. 601	Rec. 709	Rec. 2020	Cine Gamuts	Manufacturers' Gamuts
Transfer Characteristic	SDR	valid	valid	valid	valid	valid
	PQ	invalid	valid	valid	valid	valid
	HLG	invalid	valid	valid	valid	valid
	SLog3	invalid	valid	valid	valid	valid
	Manufacturers' characteristics	invalid	valid	valid	valid	valid
Range	Narrow	valid	valid	valid	valid	valid
	Full	invalid	valid	valid	valid	valid

Range Limitations designated as "invalid" and shown in red:

Range Limitations		Range	
		Narrow	Full
Transfer Characteristic	SDR	valid	valid
	PQ	valid	valid
	HLG	valid	valid
	SLog3	valid	valid
	Manufacturers' characteristics	valid	valid
Colorimetry	Rec. 601	valid	invalid
	Rec. 709	valid	valid
	Rec. 2020	valid	valid
	Cine Gamuts (DCI-P3, ACES)	valid	valid

	Manufacturers' Gamuts	valid	valid

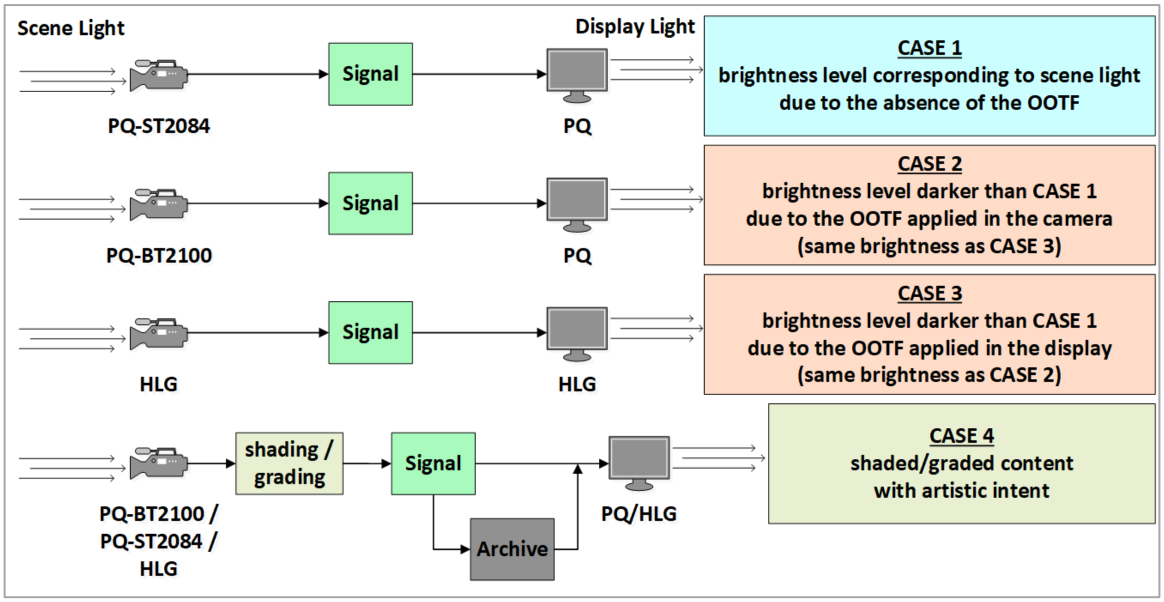
Mapping Type Limitations designated as "invalid" shown in red

Tone Mapping Scene Light		to				
		SDR	PQ-ST2084	PQ-BT2100	HLG	SLog3
from	SDR	none	valid	valid	valid	valid
	PQ-ST2084	valid	none	invalid	invalid	invalid
	PQ-BT2100	valid	invalid	none	invalid	invalid
	HLG	valid	invalid	invalid	none	invalid
	SLog3	valid	invalid	invalid	invalid	none
	Manufacturers' characteristics	valid	invalid	invalid	invalid	invalid

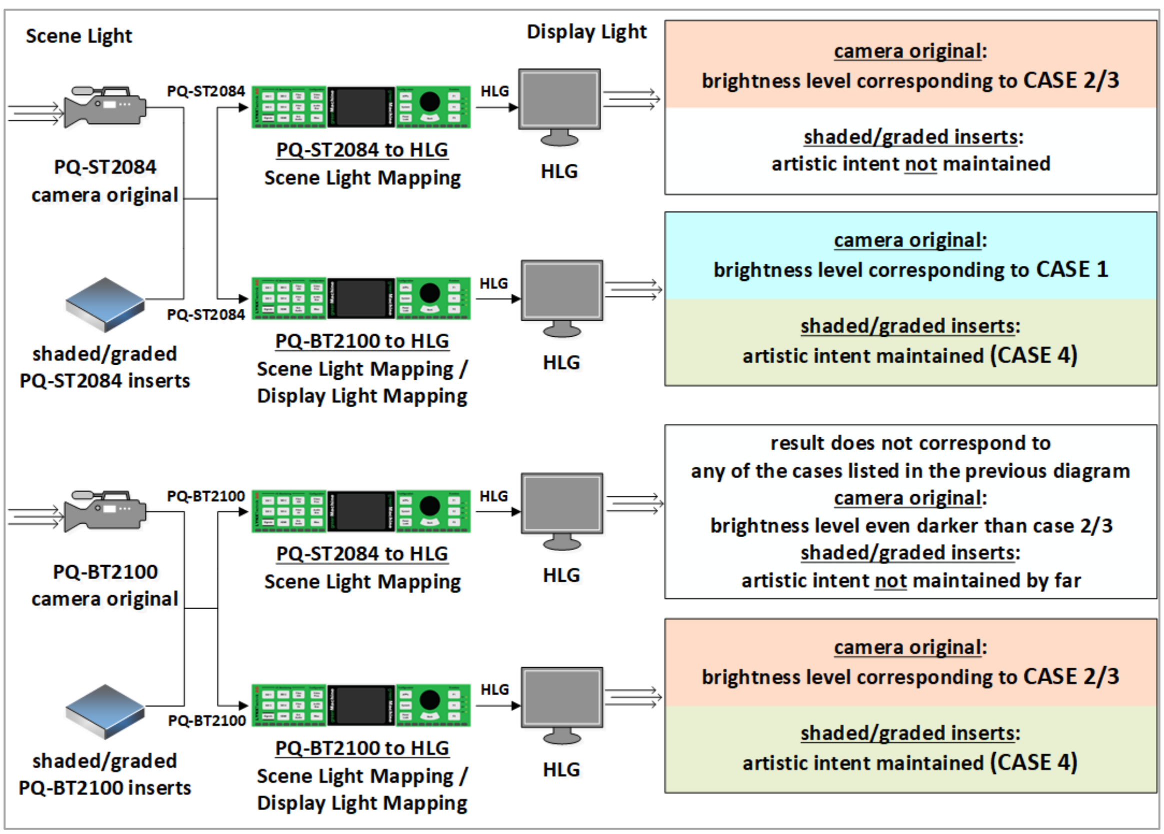
Tone Mapping Display Light		to				
		SDR	PQ-ST2084	PQ-BT2100	HLG	SLog3
from	SDR	none	invalid	valid	valid	invalid
	PQ-ST2084	invalid	none	invalid	invalid	invalid
	PQ-BT2100	valid	invalid	none	invalid	invalid
	HLG	valid	invalid	invalid	none	invalid
	SLog3	invalid	invalid	invalid	invalid	none
	Manufacturers' characteristics	invalid	invalid	invalid	invalid	invalid

Direct Mapping Scene Light		to				
		SDR	PQ-ST2084	PQ-BT2100	HLG	SLog3
from	SDR	none	valid	valid	valid	valid
	PQ-ST2084	valid	none	valid	valid	valid
	PQ-BT2100	valid	valid	none	valid	valid
	HLG	valid	valid	valid	none	valid
	SLog3	valid	valid	valid	valid	none
	Manufacturers' characteristics	valid	valid	valid	valid	valid

Direct Mapping Display Light		to				
		SDR	PQ-ST2084	PQ-BT2100	HLG	SLog3
from	SDR	none	invalid	valid	valid	invalid
	PQ-ST2084	invalid	none	invalid	invalid	invalid
	PQ-BT2100	valid	invalid	none	valid	invalid
	HLG	valid	invalid	valid	none	invalid
	SLog3	invalid	invalid	invalid	invalid	none
	Manufacturers' characteristics	invalid	invalid	invalid	invalid	invalid



Relevant cases of PQ and HLG looks (see chapter 3.2.1. "PQ")



Resulting looks when cross-converting from PQ to HLG in relation to the cases shown in the previous figure (see chapter 3.2.1. "PQ")

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www.lynx-technik.com

Contact Information

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