Please note:
This document is a supplement to the Digital Production Partnership’s Technical Delivery Specifications, and should be read in conjunction with the relevant associated documents. Additional information can be found here.

These documents also contain several elements that require discussion and agreement with the broadcaster before production begins. Please read through the documents and make sure you have had the discussions before you begin production.

UHD standards and practices are evolving quickly and the processes for High Dynamic Range (HDR) production are not yet fully understood. This document will receive regular updates as more is learned about these processes. Check that you are using the latest version of this and any related documents.

The DPP welcomes comments and suggestions from those involved with the production and delivery of HDR programmes.

DPP Guidance for High Dynamic Range programmes

This delivery supplement details the DPP guidance for technical and operational practices used during the production of HDR programmes using either the Perceptual Quantization (PQ) or the Hybrid Log-Gamma (HLG) options of ITU-R BT.2100. For the avoidance of doubt, any reference to ITU-R BT.2100 also includes ITU-R BT.2020, including colour gamut and levels.

High Dynamic Range Television delivers images that look correct on displays that produce much brighter highlights, and improved detail in dark areas.

It is vital that viewers have a comfortable viewing experience with consistency between scenes and at junctions between programmes especially between HDR and Standard Dynamic Range (SDR) programmes.

There will only be a single version of an HDR programme so account should be taken of the need to be able to derive conventional SDR signals from the HDR programmes that have been produced in PQ or HLG.
1. HDR Production Guidance

1.1. Production using PQ

Production in PQ has no additional complexity when compared to SDR production. During capture, the scene may be exposed to produce the desired appearance on a reference monitor. The difference in PQ production versus SDR production is that it is possible to encode information above the capabilities of the reference monitor if that monitor cannot reach 10,000 cd/m². In this case, more detail may be revealed on a display with a higher peak luminance level.

During set-up, camera controls such as gain and shutter and others may be pre-adjusted to make best use of camera sensor capabilities to establish a creative intent.

During capture, the iris may then be adjusted taking consideration of the reference levels listed below as well as the creative intent.

1.2. Production using HLG

HLG has been designed to enable a straightforward migration towards HDR television production, with few changes to SDR production working practices.

The compatible nature of the HLG signal allows standard dynamic range monitors to be used in non-critical monitoring areas. HDR monitors are only necessary for critical monitoring, such as when colour grading, camera racking and monitoring programme and preview outputs in a production gallery.

2. Displays

HDR images should be viewed on displays that support the ITU-R BT.2100 colour space (this is identical to the ITU-R BT.2020 colour space).

2.1.1. PQ Displays

PQ signals should be viewed on a display that supports the full ITU-R BT.2100 colour gamut and can reach 10,000 cd/m² for peak white signals. In practice, monitors that are available cannot reach the extent of the ITU-R BT.2100 gamut or the peak brightness of the PQ signal.

Monitors that support PQ may, or may not, include tone-mapping to bring high brightness signals down to the capability of that monitor. Some monitors may clip at their peak output capability (e.g. 2000 cd/m²). Some monitors may contain tone mapping that provides a soft-clip. If a soft-clip is desired for use with a monitor that only provides a hard clip, an external Look-up-table (LUT) can be employed to provide any desired tone mapping.

If the ITU-R BT.2100 PQ signal is presented to a monitor that expects a ITU-R BT.709 input, the image will appear dim and washed out; colours will be desaturated and there will be some hue shifts. An external 3D LUT can provide the down mapping function necessary to bring both colour and brightness into the ITU-R BT.709 colour volume, thus allowing satisfactory display on the legacy ITU-R BT.709 monitor. While this allows viewing on the ITU-R BT.709 monitor, the resulting images should not be used to make critical judgements of the HDR production.

2.1.2. HLG Displays

For best results, when displaying HLG signals on SDR screens, the SDR monitor should support the ITU-R BT.2100 colour monitoring. However, for simple confirmation of the presence or absence of a signal, ITU-R BT.709 colour monitoring may be sufficient. ITU-R BT.709 colour monitors will, however, show a de-saturated image with visible hue shifts.

High quality HLG programmes can be produced using conventional 10-bit infrastructure and 10-bit production codecs, with similar bitrates used for standard dynamic range production. The use of 12-bit production systems will, however, give greater headroom for downstream signal processing.
3. Reference Level Guidance

Currently there is not enough experience for accurate and consistent PQ or HLG reference levels requirements to be published. For guidance, the tables below give indicative figures for both standards. The brightness of PQ and HLG HDR produced content is expected to vary around the nominal reference levels, offering room for artistic freedom.

For operational guidance, the terms of %PQ and %HLG are used. These percentages represent signal values that lie between the minimum and maximum non-linear values normalised to the range 0 to 100%.

3.1. PQ Reference

To select the optimum indoor reference level, skin tones from both broadcast content and home cinema release content were analysed. By segmenting HDR indoor and outdoor scenes, it was found that outdoor skin tones are an average of 1.7 stops brighter than indoor skin tones. Assuming a 1.7 stop increase in brightness from an indoor to outdoor scene, the exposure for an 18% grey card outdoors would be set to 45 %PQ.

<table>
<thead>
<tr>
<th>Tentative reference levels for PQ production</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>18% Grey Card</td>
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<tr>
<td>17</td>
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<tr>
<td>Diffuse White</td>
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</tbody>
</table>

3.2. HLG Reference

For HLG content, it is suggested that such variations be limited to around +/- 0.5 stops (scene light) to avoid uncomfortable changes in brightness between dark and bright content items. It may be possible to relax these constraints in due course, once objective measures for brightness have been adopted. In practice the nominal levels should be used for studio content under controlled lighting, with the upper and lower bounds, for example, used in daylight outdoor and indoor scenes.

<table>
<thead>
<tr>
<th>Tentative reference levels for HLG production on a 1000 cd/m² display</th>
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<tbody>
<tr>
<td>Reflectance</td>
</tr>
<tr>
<td>cd/m²</td>
</tr>
<tr>
<td>18% Grey Card</td>
</tr>
<tr>
<td>90% Reflectance Card</td>
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<tr>
<td>Graphics reference</td>
</tr>
</tbody>
</table>

4. Using SDR content in HDR programmes

As this is an evolving area, Recommendations and Standards governing the use of SDR content in HDR programmes are still being finalised by the relevant Standards bodies. When published, these Recommendations and Standards will be integrated into the relevant DPP delivery specifications. In the interim, this supplement provides a general overview and operational guidelines.

There are two options for processing SDR material into HDR programmes.

**Option 1** simply maps the SDR images into the HDR signal, maintaining the dynamic range of the original image. This method does not change how the SDR content will look, it will display on the PQ HDR reference monitor the same as it displayed on the reference SDR monitor.

**Option 2** where the SDR material is boosted in level and/or non-linearly stretched to enhance/brighten highlights and/or darken areas of the picture. Such methods should be used with care as some content may suffer if automatically up-converted without suitable creative and
technical control being applied. Where this content is then displayed on SDR equipment, it may not produce the expected results.

Currently, unless a second version of the programme is made and graded for SDR, Option 1 is the preferred method.

4.1. SDR into PQ

Standard dynamic range ITU-R BT.2020 content should be converted to PQ by applying the ITU-R BT.1886 display EOTF and then applying the inverse PQ EOTF. As a guide, the peak signal of standard dynamic range content should be set to approximately 100 cd/m$^2$ or 51% PQ.

This method means subsequent HDR-to-SDR down conversion, performed by dynamic processing (where the HDR signal is analysed and then appropriately tone-mapped down to a target brightness) will produce the same SDR signal as in the original content. That is, the round-trip SDR-to-PQ-to-SDR, will result in no change to the SDR signal.

4.2. SDR into HLG

The process of converting SDR content into HLG is mathematically reversible meaning, when the HLG signal is converted for display on SDR equipment, the SDR material is not degraded (other than some minor re-quantisation) compared with the original SDR content.

Both SDR ITU-R BT.2020 and ITU-R BT.709 content can simply be-remapped in to the HLG HDR container.

5. Conversion

Transcoding between PQ and HLG signals is specified in the report ITU-R BT.2390. When the peak brightness of the HLG and PQ displays are the same, the original and transcoded signals will look identical.

Typically, for PQ content the brightness of low-lights and mid-tones remains the same, regardless of the peak brightness of the display. Brighter PQ displays offer increased headroom for specular highlights, but the overall image brightness remains unchanged.

HLG, however, is based on relative brightness. As the display’s peak brightness increases so does the brightness of the entire image. The headroom for specular highlights is constant number of stops, but the brighter image makes it suitable for viewing in brighter environments.

When, for example, a 4000 cd/m$^2$ PQ signal is transcoded to HLG using the method specified in ITU-R BT.2390, it will appear identical on a 4000 cd/m$^2$ HLG display but it may appear darker when shown on a 1000 cd/m$^2$ HLG display in brighter environments.

As the PQ and HLG systems have different characteristics, a format conversion rather than a simple transcode is required.

5.1. Baseline PQ to HLG Conversion

The simplest method for conversion from any peak brightness PQ signal to HLG is provided by combining a PQ EETF e.g. as described in section 5.4.1 of ITU-R BT.2390, with the transcoding method specified in Section 7 of ITU-R BT.2390.

The EETF is first applied to the PQ signal to convert it for a target display of 1000 cd/m2. The HLG inverse EOTF for a 1000 cd/m$^2$ display (gamma = 1.2) is then applied to derive the HLG signal.

5.2. HLG to PQ

When converting between HLG and PQ signals, a straightforward transcode is possible, as specified in ITU-R report BT.2390. However, a target PQ display brightness of 1000 cd/m$^2$ is recommended to ensure consistent brightness between the HLG and PQ signals.