High Dynamic Range
The Best TV Picture You’ve Ever Seen

Broadcast and Professional Products
Hitachi Kokusai Electric America
Introduction to HDR

Common HDR Misconceptions

- HDR is independent of resolution and color gamut.
- HDR is not more brightness, it’s detail in the tonal RANGE.
- HDR is not a format war. They all accomplish similar things.
- HDR can be compatible with today’s SDR displays.
- HDR video in not the same as HDR photography.
Agenda

✔ Why HDR?
✔ SDR - HDR Comparison Images
✔ Why HDR for HDTV?
✔ Standards & Terminology
✔ Requirements for HDR
✔ Wide Color Gamut & HDR Profiles
✔ Operational Considerations
✔ Compatibility with SDR
✔ Consumer HDR

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A sip of water from a fire hose.
Why HDR?

- **NTSC B&W 525**: 1936 - 1940
- **NTSC Color 525**: 1953
- **ATSC HDTV 720/1080**: 1992
- **ATSC 3.0 UHD-TV 2160 HDR**: 2017

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What is High Dynamic Range?

HDR is an attempt to more closely match the way the Human Visual System actually sees things in real life.

HDR increases the difference in light intensity between the darkest and brightest elements of a TV picture.

The human eye has an exceptionally large dynamic range of 12 - 16 f stops and a contrast range of 30,000:1 (without adaption).
“HDR provides substantially increased [peak] display brightness offering detail in highlights and reflecting objects, it also provides greater detail in dark areas.”

“The HDR image formats should have, where appropriate, a degree of compatibility with existing workflows and infrastructure.”

“Modern displays are capable of reproducing images at a higher luminance, greater contrast ratio and wider color gamut than is conventionally employed in program production.”
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SDR - HDR Comparison (Simulated images)

HDR off

HDR on
SDR - HDR Comparison (Simulated images)
SDR - HDR Comparison *(Simulated images)*

HDR off

HDR on
SDR - HDR Comparison *(Simulated images)*

HDR off

HDR on
Why HDR for HDTV?

World-wide average TV viewing distance is about 9 feet.

- That’s too far away to see the full resolution of 4K.
- 4K/UHD maximum viewing distance is about 6 feet for 65” TV.
- At average distance of 9’ the optimum size is 4K/UHD TV is 105”
Why HDR for HDTV? (cont.)

HDR is easily visible at average viewing distances.

UHD full resolution may be barely visible. HDR has far more visible impact than resolution for most consumers.

HD-HDR (also called HDR+ / UHD Lite) has about one-quarter of the requirements for workflow, storage and bandwidth of 4K/UHD.

HD-HDR is deliverable today by satellite, OTT & cable, ATSC 3.0

HDR bandwidth increase of about 25% increase in bandwidth.
Methods for Improving Pictures

High Dynamic Range

- Resolution
- Color Gamut
- Bit Depth
- Frame Rate
Industry quotes on HD-HDR:

Paul Turner – Telestream: “A well set up 1080p HDR image will blow away an SDR 4K image in almost every respect.”

Netflix - HDR is much more important (than 4K). “Over the past 15 years, we’ve had plenty of increments of pixels and pixel count eventually stopped being interesting.”

EBU (TR 037)- Advanced 1080p Format. (Also known as HD+ and UHD Lite). An increase in spatial resolution alone will not provide a sufficient boost in the viewing experience.
Advanced HDR

... The Devil is in the Details
History of Dynamic Range

Today’s camera gamma curve is based on the CRT. The CRT characteristics are standardized as BT.1886. This limits the display’s peak white to 100 nits.

**BT.709 was established in 1934.**

Modern displays are capable of higher luminance, contrast ratio and wider color gamut than is employed in program production.
The Camera Gamma Curve was established for CRTs, created in 1934. It is no longer relevant for digital code values and modern displays.
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**HDR Related Standards**

**ITU-R BT.709** – AKA Rec709 standardizes the format of high-definition television, having 16:9 aspect ratio.

**ITU-R BT.2020** – Rec2020 defines various aspects of ultra-high-definition television (UHDTV) with standard dynamic range (SDR), including picture resolutions, frame rates, progressive scan and bit depths.

**ITU-R BT.2100** – defines various aspects of high dynamic range (HDR) video such as display resolution (HDTV and UHDTV), bit depth, Bit Values (Files) to specify, chroma subsampling, and color space.

**ST 2084** – This standard specifies an EOTF (the Barton PQ curve). It also specifies an EOTF characterizing high-dynamic-range reference display used primarily for mastering non-broadcast content.

**ST 2086** – Specifies the metadata items to specify the color volume (the color primaries, white point, and luminance range) of the display that was used in mastering video content.

**ST 2094** – Specifies the content-dependent Color Volume Transform metadata for a set of Applications, a specialized model of the color volume transform defined by the core components document SMPTE ST 2094-1.

**ARIB STD-B67** – Hybrid Log-Gamma (HLG) is a high dynamic range video standard that was jointly developed by the BBC and NHK. HLG defines a nonlinear transfer function in which the lower half of the signal values use a gamma curve and the upper half of the signal values are logarithmic.
HDR Terminology

HDR – High Dynamic Range TV (ITU-R BT.2100)
WCG – Wide Color Gamut – anything wider than Rec.709, DCI P3, Rec.2020
SDR – Standard Dynamic Range TV (Rec.601 or Rec.709 or Rec.2020)
PQ – Perceptual Quantizer for HDR signals (SMPTE ST 2084, ITU-R BT.2100)
Ultra HD Blu-ray – HDR disc format using HEVC, HDR10, and optionally Dolby Vision
Dolby Vision – 12-bit HDR, BT.2020, optionally Dolby Vision dynamic metadata
HDR10 – 10-bit HDR using BT.2020, PQ, optionally static metadata
HLG – Hybrid Log Gamma Transfer Function for HDR signals (ITU-R BT.2100)
UHD Alliance Premium Logo – High-end HDR TV requirements Rec.709, P3 or Rec.2020
MaxCLL – Maximum Content Light Level
MaxFALL – Maximum Frame Average Light Level
Mastering Display Metadata – SMPTE ST 2086 (min/max luminance, color volume)
DMCVT – Dynamic Metadata for Color Volume Transforms – SMPTE ST 2094
HFR – High Frame Rate (100 & 120 fps)
HEVC – High-Efficiency Video Codec (ITU-T H.265) – 2x more efficient than AVC
New HDR Terminology

OETF = Opto-Electronic **Camera Transfer Function**
A digital code value for the camera gamma curve

EOTF = Electro-Optical **Display Transfer Function**
A digital code value for a monitor or TV display

OOTF = Opto-Optical Transfer Function

**Adjusted System:** “Glass to Glass” entire path of the signal

Luminance is measured in nits = 1 candela per meter square
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Camera Signal Chain

Scene Light → OETF → Video Signal → EOTF → Display Light

Encoding

Camera → Video Signal

Decoding

Signal → Display

OOTF
Display Luminance

Movie theaters are a highly controlled environment. Television viewing is an uncontrolled environment.

*Cinema & TV are very different viewing environments.*
A minimum of 10 bit quantization is required for HDR. It offers a wider range of tones and colors needed for HDR & WCG.
HDR – Links in a Chain

Every link in the chain must be capable of passing or processing HDR.

HDR is not just a camera or a display curve. It’s a SYSTEM.
HDR – Links in a Chain
Bit Allocation in HDR Cameras

The Human Visual System has a non-linear sensitivity curve to brightness. Higher bit-depth is required in the dark to mid-tones areas of the picture.
Wide Color Gamut

In 1931, CIE established the 2D Chromaticity Diagram.

CIE was first to describe the perception of colors in a quantifiable manner.

Rec.601 & Rec.709 are similar.
Wide Color Gamut (Volume)

White is full brightness of each color. As bright colors come closer to white, they become less saturated.

Current HDR/WCG displays must display at least 90% of DCI-P3.

No current monitor or TV can display the full BT.2020 color gamut.
Multiple HDR Profiles

Hybrid Log-Gamma (HLG). No Metadata. SDR Compatible*

PQ/ ST 2084 (Consumer HDR-10) Static Metadata

HDR10+ Dynamic Metadata. (Non-Proprietary) Future

DolbyVision (Proprietary) Dynamic Metadata

*Modern Displays
Differences between HDRs

- **SDR**
  - BT.709

- **Static HDR-WCG**
  - HLG & PQ

- **Dynamic HDR-WCG**
  - DolbyVision
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Differences between HDR Profiles*

Hybrid Log-Gamma - ARIB STD-B67. For live Broadcast TV
The HLG curve works with traditional displays (BT.1886)

PQ / ST 2084 –HDR-10. 10-bit.
Color and tone grading added later in post. Static Metadata for Movies.

Dolby Vision – 12-bit. Same HDR curve as PQ. Post graded color & tone.
10,000 nit target. Dynamic metadata. License required

* HLG & PQ are the only world standard HDR curves.
All other HDR log curves must be converted for distribution.
“Artistic Intent” & Metadata

PQ and Dolby Vision use metadata and are mostly for movies and cinema. The director’s intent is put in metadata and that controls your TV display.

NOTE: TV game shows and news sets are flat lit. They will look similar to SDR unless lighting is adjusted to be more “dramatic”.
HDR / SDR Compatibility

HDR adoption requires how legacy SDR sets will display HDR.

**HLG – no metadata.** A more compatible “hybrid” curve for traditional TVs.

PQ curve is less compatible. **Static (or no metadata).**

Dolby Vision is the least compatible. **Dynamic metadata and 12 bits.**

*There’s no guarantee that a single HDR will be best for all situations.*
# HDR / SDR Compatibility

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**Note:**
- HLG: Best for live TV broadcast.
- PQ/HDR10: Better for OTT/DVD content.
- Dolby Vision: Best for movies, proprietary technology.
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HDR OOTF Transfer Curves

Hybrid Log-Gamma is more similar to the BT.709 gamma curve up to 65%
The HLG curve follows BT.709 and is more compatible with SDR TV
HLG & SDR Compatibility

4K HDR monitor (HLG)  HD SDR monitor (HLG)

HLG “Hybrid” Log-Gamma Curve is more compatible with SDR displays.
Using PQ on a SDR display would make the picture brighter at A and darker at B, creating a low contrast image.
PQ & SDR Compatibility

4K HDR monitor (PQ)
HD SDR monitor (PQ)

The PQ curve will appear grey, muddy & washed out on an SDR display.
HDR Workflow Considerations

How can I start using High Dynamic Range?
What is the most compatible HDR Profile?
Live Workflow – Compatible HDR/SDR Shading?
Mixing various SDR sources in HDR Workflow?
Delivery of SDR and/or HDR?
Broadcast Delivery of Simultaneous HDR and SDR?
Mixed Sources in HDR Production

**ITU-R BT.2408-0**

The HDR image system should have a degree of compatibility with existing workflows and legacy infrastructure.

Live production must handle many different sources and intermix HDR & SDR material.
HDR and SDR camera “look”

The HDR signal has to be converted to SDR for wide distribution. *It should look identical to the SDR signal from a SDR camera.*

The images within a scene have a different “look” for SDR and HDR

HDR & SDR are not fully compatible. They have to be converted.
HDR/SDR Compatibility

Required conversions for Broadcast HDR & SDR formats

- Dynamic Range: BT.2100 ➔ BT.709/BT.1886 (display gamma)
- Color Space: BT.2020 ➔ BT.709
- Bit Depth: 10 bit ➔ 8 bit (Broadcast)
- Spatial Resolution: 2160 (4K) ➔ 1080/720 (HD)
- Temporal Resolution: 60 Hz Progressive ➔ Interlace
- Video coding: HEVC ➔ AVC or MPEG-2 (Broadcast)
Hitachi’s 4K HDR camera is available with two simultaneous outputs – one HDR (HLG or PQ) and another SDR output (BT.709).

The camera exposure is adjusted for the HDR HLG output, and the SDR signal is derived by applying inverse gamma, a gain offset of -9 dB, and then a conventional BT.709 OETF.
Inverse Gamma – Gamma Mapping Process

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Today’s HDR/SDR shading...

Depending on the profile, camera video shaders should adjust the picture primarily for the “downconverted” SDR.

If SDR is correct, HDR will be OK. The SDR lies within HDR.

However, shading only for HDR will clip the SDR picture.
Camera Shading ...Tomorrow

The camera shaders should be able to manage the cameras in the conventional manner, using SDR monitoring from the CCUs.

The HDR signals will track the offset iris adjustments made for SDR.
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Simulcast Delivery via LUT

Mobile Production Truck

SDR Feed

SDR

HDR

LUT BOX

Master Control distribution

LUT BOX

SDR

HDR

HDR to SDR

HLG to PQ

PQ to HLG

SDR Feed
Simulcast via CCU Conversion

CU-UHD4000

Inverse Gamma/Gamut Mapping

Mobile Production Truck

SDR Feed

SDR

HDR

Master Control distribution

3D LUT

SDR

HDR

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Broadcast SDR/HDR Delivery

Stations will be able to deliver simulcast HDR/SDR with ATSC 3.0

ATSC 3.0 A/341 Standard – SL-HDR1

Technicolor’s Single Layer (SL) Transmission System

Encodes a SDR signal with HDR Metadata for transmission

Provides SDR & Reconstruction of HDR signal at the TV receiver.
Consumer TVs & HDR Standards

ULTRA HD PREMIUM TV specs:

Image Resolution: 3840×2160

Color Bit Depth: 10-bit, BT.2020 color space (90% of DCI-P3 colors)

High Dynamic Range and SMPTE ST2084 EOTF

Spec on nits brightness:

LCD = More than 1000 nits peak brightness & less than 0.05 nits black (today 2,000 nits)

OLED = More than 640 nits peak brightness & less than 0.0005 nits black (today 1,000 nits)
## HDR Support in TVs

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Most major TV manufacturers have announced support of HLG for new models.
Most OTT is available with HDR and is either HDR10 or HLG.
Mobile devices receiving HDR are allHDR10.
Worldwide HDR TV Forecast

HDR Compatible 4K TVs (luminance above 650 nits)

Forecast = 245M UHD HDR TVs by 2022.
Comparison of SDR & HDR *(simulated for SDR display)*

ORIGINAL 4K Content HDR Curve: PQ, 1000 nits, DCI-P3 color, Resolution: 3840x2160

Simulated 4K SDR: BT.709 Gamma, 100 nits, BT.709 color space, Resolution: 3840x2160

Workflow:
The simulated SDR clip was achieved by re-grading the HDR clip until it was visually indistinguishable from a SDR TV.

The HDR and simulated SDR clips were then composited with a moving wipe.

**HDR/SDR comparison test clip**
Thank You
For more information...

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Key Questions & Answers

1) Why do we advocate HD-HDR instead of UHD-HDR?
   At average Viewing distance you can’t see the full resolution of UHD/4K

2) Why is there significant HLG compatibility with newer SDR flat panels?
   The brightness of today’s SDR flat panels far exceeds BT.709@ 100 nits

3) What is the Primary difference between HLG and Dolby PQ?
   HLG is for Live Broadcast TV vs. Dolby PQ for Post-Produced Movies

4) How many bits are typical for SDR and how many for HDR?
   8 bits for SDR. 10 bits for HDR. (Dolby Vision requires 12 bits)
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