Elements of High Dynamic Range Video

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Abstract

Over the past seven decades, display technology has progressed to the point where 4K/Ultra HD video is now the gold standard. 4K resolution yields four times the number of pixels as HD video, but depending upon the size of the display and the viewing distance, there may be no perceptible difference between an HD image and a 4K/UHD image. Adding HDR - High Dynamic Range to a 4K/UHD image is the differentiator that takes 4K/UHD far beyond what HD can offer. HDR enhances the quality, rather than the quantity, of the pixels being displayed since it provides richer colors and greater contrast.

This document will help you understand the core concepts, technologies, and practical considerations related to HDR.

white paper

Why HDR?

As video technology has progressed, the transition from HDTV to 4K/Ultra HD video echoes the earlier evolution from standard definition to high definition TV. The SD to HD transition was easily recognizable to the casual viewer. It involved diverse changes such as replacing CRTs with flat panel displays, altering the aspect ratio from 4:3 to 16:9, increasing the screen size, and improving display resolution. However, the progression from HD to 4K/UHD initially involved only higher resolution, so noticing an improvement in video quality was highly-dependent upon the specific application.

When a viewer is close to the display, as in digital signage or computer imaging applications, 4K/UHD's increased video resolution is readily apparent. However, as viewing distance increases, 4K/UHD's higher resolution becomes less noticeable - see Figure 1. For displays that have improved color reproduction and a greater dynamic range, i.e. a larger span between the brightest and the darkest reproducible luminance, the improvement in image quality is noticeable and appreciated independent of the display's physical size and regardless of the viewing distance.

When High Dynamic Range – HDR is added to a 4K/UHD display, the differences between 4K/UHD and HD are striking. HDR video technology incorporates greater color accuracy and a wider range of displayed luminance than 4K/UHD that lacks HDR. When

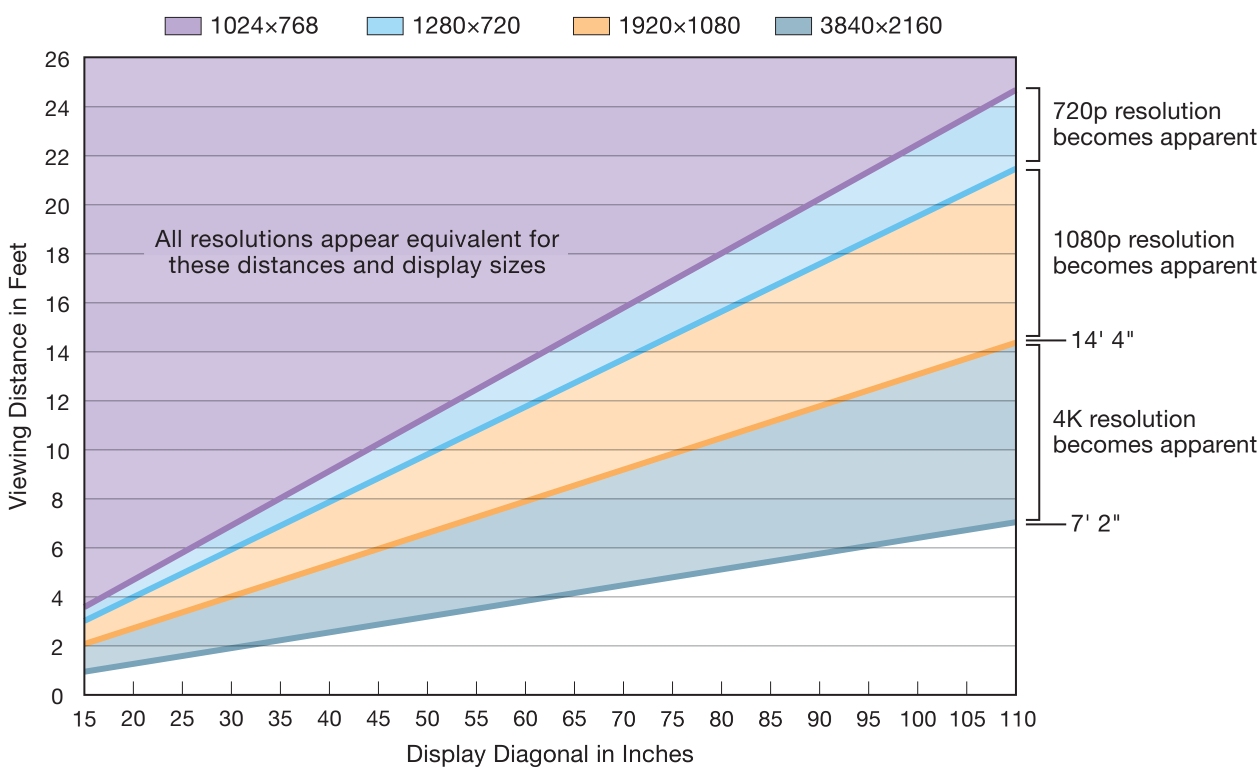

Figure 1: The benefits of higher resolution are dependent on image size and viewing distance. See Appendix One for details and derivation.

High Dynamic Range Image

Standard Dynamic Range Image

Figure 2: High dynamic range video technology enables a wider color gamut and a greater range of light and dark to be displayed, making the image more realistic and revealing more detail.

you view the two images in Figure 2, it is easy to see the impact that HDR provides when compared to an SDR image. HDR enables a wider color gamut and a greater range of light and dark, making images more realistic and revealing more detail. The wider color gamut is appreciable in the greater color saturation within the HDR image as a whole, especially in the clouds and blue sky. With HDR, both bright and dark areas of the image are improved. As a result, additional HDR image detail is apparent in the dark area of trees to the right of the Eiffel Tower. All of these benefits can be appreciated regardless of pixel resolution.

New video technologies and standards must be brought to market in order to make these HDR improvements possible. Improved color accuracy can be realized by adopting the ITU-R BT.2020 color gamut along with greater color bit depth to increase the visible color volume. Manufacturers must develop displays that can provide higher maximum brightness and deliver more detail at low luminance levels. Video source devices must provide content in HDR. To ensure interoperability for all this updated equipment, new video transport formats are needed.

New Video Technologies That Support HDR

HDR was designed to reproduce a range of brightness levels that is much closer to that encountered in the natural world. While an incandescent light fixture can produce 6,000 nits (candela/m^2), and reflected sunlight can be over 100,000 nits, TV and Blu-ray content is typically mastered for a maximum luminance of 100 nits. Thus, standard dynamic range video is unable to reproduce the luminance levels that are present in many real-life situations. See Figure 3. To attain more realistic luminance levels envisioned for HDR, much brighter display technologies are required.

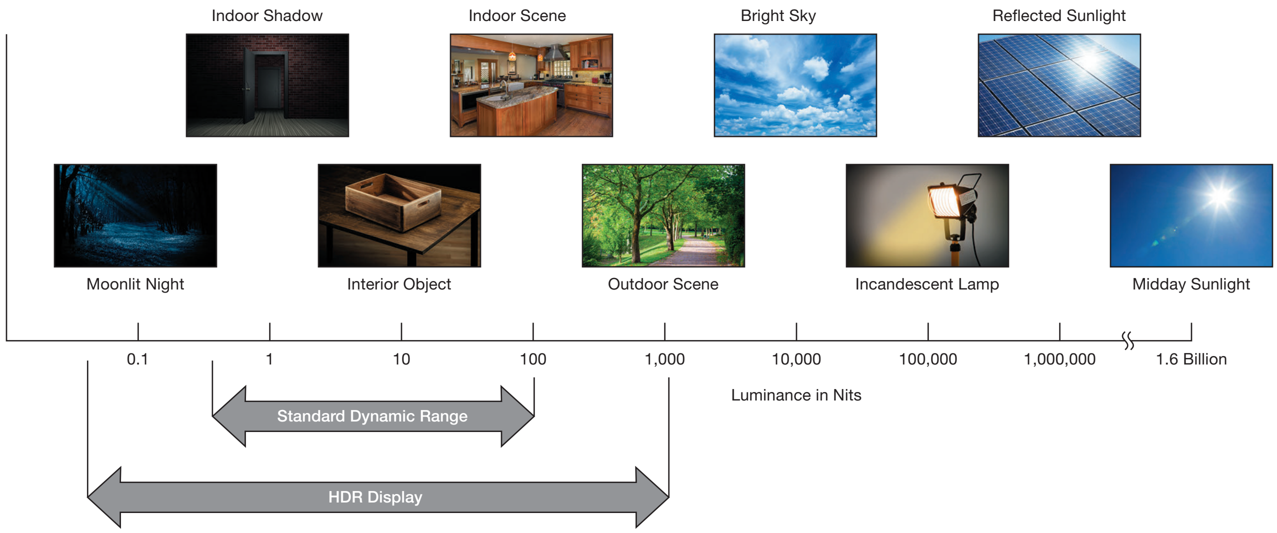

Figure 3: HDR video technology is designed to reproduce a broader range of luminance levels and a more realistic viewing experience.

Laser Projection

Professional-level large venue video projectors have always been able to generate very high brightness levels, and recent developments in laser projection provide the added benefits of wider color gamut, higher energy efficiency, and simplified maintenance by eliminating the lamp as light source. The new HDR-capable projectors incorporate advances in light modulation along with the high intensity light source to achieve the wide range of luminance levels required for HDR.

Laser projection systems that use three laser sources, one for each primary color, have inherent advantages in color accuracy. Projection systems that use a single white light source employ color wheels, phosphors, and filters to generate color. Each of these techniques can add some error to the resulting color output.

OLED

An OLED flat panel display, consisting of an array of organic light emitting diodes, is inherently advantageous for HDR because each individual pixel emits its own light and can be turned off completely. In contrast, LCD displays depend on switching the liquid crystals at each pixel to block a backlight – a process that allows some of the backlight to leak through. Thus, OLED displays have better control of low luminance levels than LCD or projector displays. Current OLED technology however, cannot yet generate high luminance levels to match LCD displays.

Similar to three-laser projectors, OLED displays also have inherent advantages in color accuracy because each pixel emits red, green, and blue primary colors with high consistency.

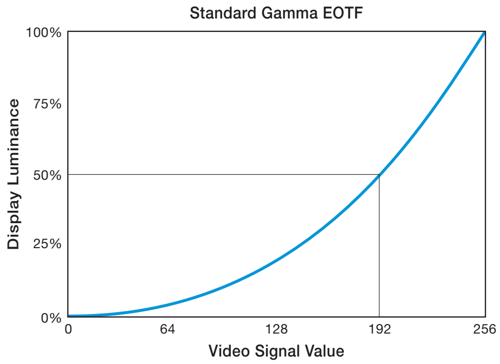

Figure 4: Gamma EOTF is the power law relationship between a display's video input signal value and the luminance – the amount of light it generates.

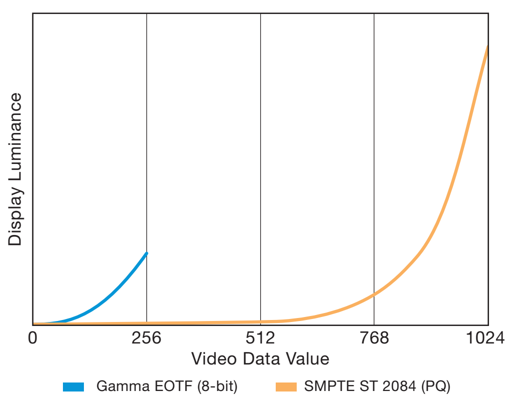

Figure 5a: Differences between traditional 8-bit gamma and 10-bit SMPTE ST 2084.

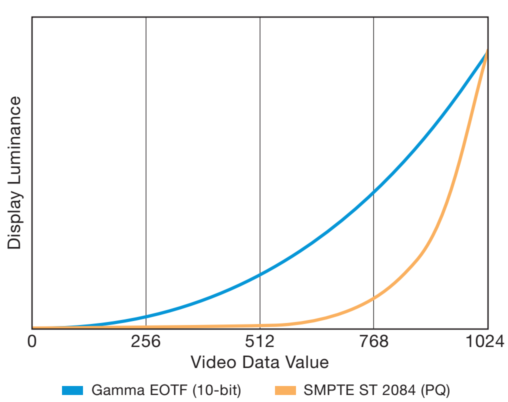

Figure 5b: Gamma can be stretched to accommodate HDR, but the response will still be different from SMPTE ST 2084.

LCD

LCD flat panel displays can achieve high luminance levels by increasing the intensity of the backlight. High dynamic range is accomplished by dividing the backlight into individual zones with brightness levels that can vary independently according to the requirements of the video content. Compared to OLED, LCD displays have the advantages of lower cost and higher maximum brightness, but have coarser control of low luminance levels.

LCD displays generate color by filtering the white backlight to form red, green, and blue subpixels. To provide the accuracy needed for HDR, the color characteristics of the backlight and filters need to be well matched.

Enhanced EOTF – Electro-Optical Transfer Function

The EOTF – Electro-Optical Transfer Function - of a display defines the relationship between the display's electrical input signal and the output luminance it generates. The human eye is more sensitive to luminance changes at low intensity than at high, so an efficiently designed EOTF would devote greater signal bandwidth to encode low intensities and less signal bandwidth to encode high intensities.

Early in the development of video technology, it was recognized that the EOTF of cathode ray tubes - CRTs - closely matched the response of the human eye, and is characterized by a power law relationship with the exponent called gamma. See Figure 4:

$$\text{Output Luminance} = (\text{Input Voltage})^{\text{gamma}}$$

This gamma relation works well for the range of luminance values that CRTs can produce, and has been standardized in ITU-R BT.1886. Even as the display market evolved and flat panel displays have replaced CRTs, the flat panel displays were designed to produce similar luminance levels with EOTFs to match CRT gamma behavior.

HDR involves much higher luminance levels than can be produced by CRTs. Human visual response to the increased luminance levels is quite different and much more nonlinear than the traditional gamma relationship, and a new EOTF is required for optimal efficiency. Dolby Laboratories initially developed the EOTF known as the Perceptual Quantizer (PQ) which has now been standardized in SMPTE ST 2084 and CEA-861.3 and is defined for a maximum luminance of 10,000 nits. Recall that traditional gamma for mastering media content typically references a maximum luminance of 100 nits. Figure 5a illustrates the difference between traditional gamma at 8 bits and low luminance versus SMPTE ST 2084 at 10 bits and high luminance. It is possible to "stretch" gamma to 10 bits and HDR luminance, but the response curves are still different, as shown in figure 5b.

Transport Formats

HDR transmission requires exchange of metadata between a source and a display so that the transmitted video data matches the capabilities of the display. This is due to the different maximum luminance capabilities of display technologies, and also due to the need for backward compatibility with traditional, non-HDR media. CEA-861.3 was released in January 2015 and defines metadata for HDR in InfoFrames and EDID. CEA-861.3 metadata is referenced and supported in the HDMI 2.0a and DisplayPort 1.4 standards.

CEA-861.3 adds a new Dynamic Range and Mastering InfoFrame (type 0x07) to identify the EOTF type and the maximum light levels of the content being transferred. The EOTF type may be standard dynamic range gamma, high dynamic range gamma, or SMPTE ST 2084. Maximum light levels are defined by the parameters MaxCLL (maximum content light level) and MaxFALL (maximum frame average light level).

On the display side, CEA-861.3 similarly adds a new EDID HDR data block (tag code 0x6) for storing the EOTF type supported by the display. See Table 1 as well as the display's preferred MaxCLL and MaxFALL values.

Type Code	Supported EOTF
0	Traditional gamma – SDR luminance
1	Traditional gamma – HDR luminance
2	SMPTE ST 2084 HDR EOTF
3	Future EOTF

Table 1: New EDID for HDR EOTF selection

In addition to 861.3, CEA has defined the HDR10 media profile for equipment and content. HDR10 calls for support of the SMPTE ST 2084 EOTF, 4:2:0 chroma subsampling for compressed video, bit depth of 10 bits per color, BT.2020 color gamut, and SMPTE ST2086, MaxCLL, and MaxFALL metadata. While the HDMI 2.0a and DisplayPort 1.4 standards specifically reference support for CEA-861.3, but do not mention HDR10, the features defined in HDR10 represent the minimum requirements for HDR equipment and content.

Dolby Vision is another HDR format that involves proprietary metadata exchange between licensed equipment. Dolby Vision also employs the Perceptual Quantizer SMPTE ST 2084 EOTF, but with additional features. It involves all the stages of video distribution from content creation/mastering to media distribution/broadcast, to playback for the end user. One major difference between Dolby Vision and HDR10 is that while HDR10 metadata is static and applies for the entire video, Dolby Vision metadata can be dynamic so that maximum light levels can vary from scene to scene. Another major difference is

Frame Rate (Hz)	Chroma Sampling	Color Bit Depth	Data Rate (Gbps)
≤30	4:2:2	10 or 12	8.91
≤30	4:4:4	10	11.14
≤30	4:4:4	12	13.36
50, 60	4:2:0	10	11.14
50, 60	4:2:0	12	13.36
50, 60	4:4:4	10	22.28
50, 60	4:4:4	12	26.73

Table 2: Video data rates needed to support the various formats of 4K HDR

that Dolby Vision uses 12-bit color depth. Dolby Vision represents a superset of HDR10 features, but its implementation on specific pieces of equipment may not be compatible with HDR10.

Data Rate Requirements

Table 2 summarizes the video data rate requirements to transmit 4K HDR video for various combinations of chroma subsampling, color depth, and frame rate. The HDMI data packing scheme for 4:2:2 sends 12-bit color by default, so it is theoretically possible to support 4K HDR with 8.91 Gbps at 4:2:2 for frame rates less than 30 Hz. Practically however, many displays and video sources support only 8-bit color at 4:2:2, and the vast majority of 4K HDR-capable equipment require at least 11.14 Gbps. 4K/30 4:2:0 with HDR is not listed because the HDMI specifications currently define only 4:2:0 color subsampling for 50 Hz and 60 Hz refresh rates. Note that at 4K/60 4:4:4, the required data rate to support HDR exceeds the 18 Gbps of a single HDMI 2.0 connection. HDR at resolutions other than 4K/UHD is possible, since the mechanisms for HDR metadata exchange are defined independently of video resolution.

In computer graphics, many 3D graphics applications already have internal HDR capability, but render at standard dynamic range due to operating system or video display limitations. The standardization of HDR video data transfer rates should unleash this capability. One early example is the Sony Playstation 4, which received a firmware update to enable HDR, even for models limited to 1080p video output.

HDR Sources and Displays

HDR content is captured using cameras that are capable of wide dynamic range, or generated using computer graphics. The appropriate metadata is then embedded in the content to enable proper playback. At the end user level, HDR sources can include UltraHD Blu-ray players, set-top boxes, and computer graphics cards. The display itself can be a source of the HDR content if it has built-in capability to receive streaming content from services such as Netflix or Amazon Video.

UltraHD Blu-ray discs support HDR playback and the Blu-ray Disc Association has specified the minimum HDR requirements to consist of H.265 encoded video stream, BT.2020 color gamut, and SMPTE 2084 EOTF. These requirements are very similar to HDR10, and Dolby Vision also can be supported by UltraHD Blu-ray.

The UHD Alliance (UHDA) is an industry group consisting of film studios, consumer electronics manufacturers, and technology companies that promotes the growth of the 4K video entertainment ecosystem. UHDA has released an “Ultra HD Premium” specification for 4K equipment that supports HDR:

- 3840x2160 image resolution
- Color bit depth: 10 bits per color
- BT.2020 color gamut, with minimum display reproduction of 90% of DCI-P3 colors
- SMPTE ST 2084 EOTF
- Either
    - o More than 1,000 nits peak brightness and 0.05 nits black level
    - o More than 540 nits brightness and 0.005 nits black level

HDR and Pro AV

Infrastructure for HDR Support

To support HDR, all equipment in the signal chain from source to display must support the exchange of the requisite InfoFrame and EDID metadata, and also meet the minimum data rate and color depth requirements. Extenders, switchers, and matrix switchers must be capable of transferring at least 11.14 Gbps to support 4K/60 4:2:0 or 4K/30 4:4:4 and 10 bits per color. Display HDR capabilities indicated in their EDID tables must

	HDMI 2.0a DisplayPort 1.4 (CEA-861.3)	UltraHD Blu-ray	HDR10	UltraHD Premium	Dolby Vision
Applicable to	Physical video connections	UHD Blu-ray media content	IP, HDMI, or other media	Equipment, distribution, content	Equipment, distribution, content
Color Bit Depth	≥10	≥10	10	≥10	≥12
EOTF	SMPTE ST 2084 or gamma	SMPTE ST 2084	SMPTE ST 2084	SMPTE ST 2084	SMPTE ST 2084
Color Gamut	BT.2020	BT.2020	BT.2020	BT.2020	BT.2020
Metadata	Static InfoFrame, EDID		SMPTE ST 2086, MaxFALL, MaxCLL		Dynamic proprietary

Table 3: Summary of HDR requirements and formats

be propagated and presented to video sources, so any switching equipment in between must process the EDID data correctly. Similarly, InfoFrame metadata from HDR sources must be transmitted to displays without being incorrectly modified by the intervening equipment of the infrastructure connecting them. Finally, the minimum 10-bit color depth must be maintained throughout.

Practical Considerations

As an emerging technology, the implementation of HDR can be inconsistent across video sources and displays as manufacturers introduce products with new and different capabilities that may not be compatible. For example, a display may support only Dolby Vision, but a source might support only HDR10, so connecting them together results in no viewable HDR image, or an image with the wrong brightness. Different manufacturers also can promote HDR capabilities in different ways so that the exact HDR capabilities may not be clear. For example, display manufacturers can claim HDR support in their branding, but without specifying the exact range of output luminance that the displays can actually reproduce. In video distribution applications where a single HDR source is feeding multiple HDR displays, care should be taken to use identical displays to ensure consistent video quality. This is similar to the practice of making sure that all displays can handle the video resolution being distributed. In terms of content protection, video sources such as UHD Blu-ray players, set-top boxes, media players, and computing devices will require HDCP 2.2 for protected 4K/HDR entertainment content.

The professional AV designer needs to be aware of the formal requirements as well as the peculiarities of HDR technology for successful system implementation. System components should be selected for end-to-end compatibility of HDR format and metadata exchange, maximum required video data rate, and content protection capability.

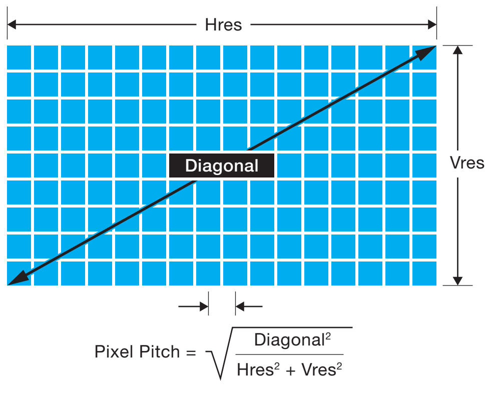

Figure 6: Calculating pixel pitch

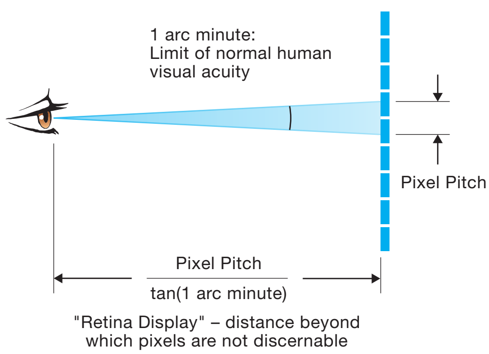

Figure 7: Deriving the optimal or "retina display" distance

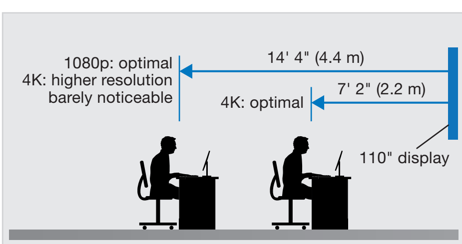

Figure 8: Upgrading a display from 1080p to 4K without increasing the size of the display cuts the optimal viewing distance in half.

Appendix One: Visual Acuity, Video Displays, and Viewing Distance

The perceptibility of pixels and hence image detail is based on 1 arc minute being the generally accepted standard of human visual acuity. An arc minute is the angle equal to 1/60 of one degree, or 1/21600 of a circle. The ability of the human eye to resolve visual details separated by 1 arc minute is the basis for 20/20 vision, or internationally, 6/6 vision.

The pixel pitch is the center-to-center distance between adjacent pixels in a digital display. Knowing the diagonal size and resolution of a display, its pixel pitch may be calculated as shown in Figure 6. For a viewer with visual acuity of one arc minute, there is a viewing distance at which the pixels just begin not to be perceptible. See Figure 7. This is the same concept as the Apple retina display, where smartphones or laptops of a certain size and resolution would have no perceptible pixels when viewed at typical distances. Some typical combinations of display resolutions and optimal or "retina" viewing distances are shown in Table 4.

In Figure 8, a viewer with normal visual acuity at a distance of 14' 4" (4.36 m) away from a 110" diagonal projection display with 1080p resolution can just barely discern adjacent pixels. Therefore, the maximum amount of picture detail that can be produced by the display is perceived at this distance. If the resolution is upgraded to 4K, but the display size is kept the same at 110", the viewer would have to move half the distance from the display to perceive all the picture detail. If the viewer remains at the same distance of 14' 4" from the display, much of the additional 4K image detail would not be perceived.

	4" Smartphone	13" Laptop	60" HDTV	60" 4K/UHD TV	110" 1080p Projection	110" 4K/UHD Projection
Horizontal Resolution	1136	2560	1920	3840	1920	3840
Vertical Resolution	640	1600	1080	2160	1080	2160
"Retina" Distance	10.5" (26.8 cm)	14.8" (37.6 cm)	7' 10" (2.37 m)	3' 11" (1.19 m)	14' 4" (4.36m)	7' 2" (2.18m)

Table 4: Typical retina display distances for various applications and display resolutions

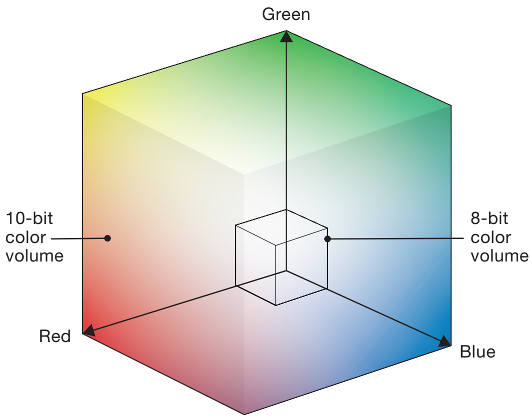

Figure 9: RGB color space

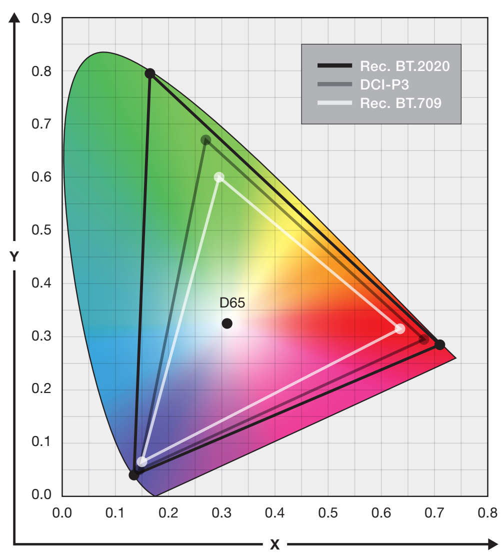

Figure 10: BT.2020 UHDTV and BT.709 HDTV color chromaticity and color gamut

Appendix Two: Color Bit Depth and Color Gamut

In RGB computer video, each pixel is composed of red, green, and blue components. The color bit depth is the number of bits assigned to each color component. For example, if 8 bits are assigned per color, then each pixel would be represented by 24 total bits, and each color can have a value from 0 to 255, where the value of the color component represents the intensity of that color. All the possible colors that can be represented by such a system can be thought of as a three dimensional volume, with each primary color occupying an axis. For each additional bit of color depth, the volume of displayable colors increases eightfold. See Figure 9.

The red, green, and blue primary colors of the above-mentioned color volume are defined by their locations on the CIE chromaticity diagram, which represents all the colors discernible by the human eye without regard to brightness. The CIE chromaticity diagram is constructed so that any color in the interior of a triangle can be represented as a combination of the primary colors that define the corners of that triangle. Thus any triangle of the diagram encloses a defined color gamut. For example, the smallest triangle in Figure 10 represents the BT.709 color gamut, whose red, green, and blue primary colors are at the respective corners of that triangle. Similarly, the corners of the middle triangle represent the primary colors of the DCI-P3 color gamut, and the corners of the largest triangle represent the primary colors of the BT.2020 color gamut.

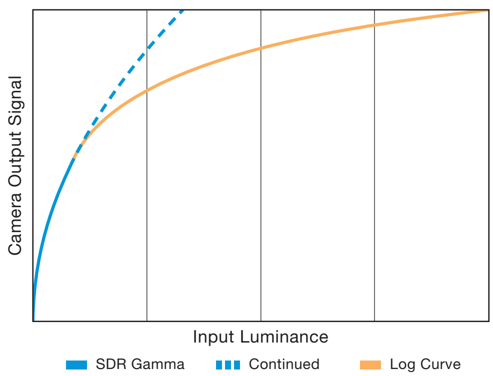

Figure 11: Hybrid Log Gamma OETF defines a gamma characteristic at low light input and a logarithmic characteristic at high input luminance to generate an HDR signal that maintains backward compatibility with the installed base of standard dynamic range displays.

Appendix Three: Alternative HDR Approaches for Backward Compatibility

While the PQ or SMPTE ST 2084 approach to HDR focuses on efficiently matching displayed brightness levels to human visual capabilities, it requires that HDR displays recognize and apply the new EOTF; otherwise, the resulting image would be too bright. Therefore, PQ is not backward compatible with the existing installed base of SDR displays. Without backward compatibility, broadcasters and other content originators that serve a general audience need to provide both HDR and SDR versions of video material, complicating production and raising costs. HDR video formats that can be compatible with non-HDR displays have been developed to address these concerns.

Hybrid Log-Gamma

Hybrid Log-Gamma – HLG was jointly developed by the BBC and NHK as an alternative approach to the Perceptual Quantizer (PQ) EOTF and is not natively compatible with PQ. HLG defines an OETF – Opto-Electronic Transfer Function which relates the input luminance sensed by a camera and the output electrical signal it generates. For low input luminance values, the camera implementing HLG generates a gamma curve, then transitions to generate a logarithmic curve for high input luminance values. See Figure 11. The HLG format does not need to insert the metadata required by PQ, allowing for a simpler production process, especially for live broadcasts. Both HLG and PQ have been adopted as HDR standards in ITU-R BT.2100 released in July 2016. While not directly mentioned in the HDMI 2.0b specification, the HDMI organization has indicated that HLG is compatible with HDMI 2.0b.

At a high level, the relationship between the optical image captured by a camera and the optical image shown by a display defines the OOTF, Opto-Optical Transfer Function, of the complete video delivery system. The OOTF may be separated into three functional blocks. The first block is the camera OETF which captures light from the scenery and converts it into an electrical signal. The second functional block represents artistic and technical adjustments to the camera output signal made at the production facility. The third block is the display EOTF, which converts the incoming electrical signal to a

End-to-End Video System OOTF

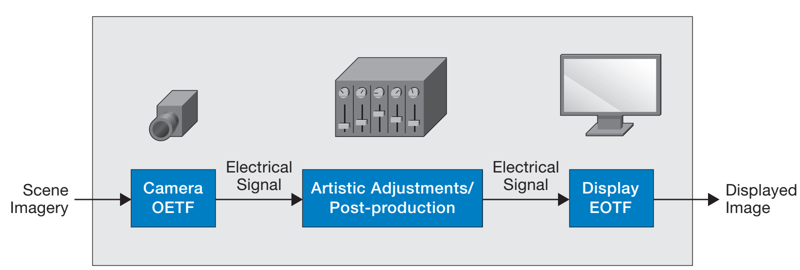

Figure 12: The relationship between the scenery captured by a camera and the final image shown at a display defines the OOTF, or Opto-Optical Transfer Function.

viewable image. See Figure 12. To increase the system's dynamic range, the entire signal chain must be upgraded.

SL-HDR1

STMicroelectronics, Philips International B.V., CableLabs, and Technicolor R&D France jointly developed the SL-HDR1 format, which has been standardized as ETSI TS 103 433 in August 2016. SL-HDR1 defines a system for streaming HDR video that is compatible with standard HEVC and AVC and employs dynamic metadata to convert streaming SDR video to HDR.

SL-HDR1 purports to be "EOTF-agnostic" where the process works with any uncompressed HDR video file regardless of how it was created. See figure 13. The SL-HDR1 specification declares that the original HDR video can be deconstructed into and SDR video plus content-dependent, dynamic metadata such as luminance levels, luminance mapping, and color correction parameters. The deconstruction process may involve manual input by a colorist to set some metadata values. After deconstruction, the resulting SDR plus metadata can be encoded and streamed using standard HEVC or AVC mechanisms by the content originator. HDR-capable equipment at the receiving end will recognize the HDR metadata and reconstruct the HDR video. If the receiving equipment is only capable of SDR, it will ignore the metadata and simply decode the SDR video.

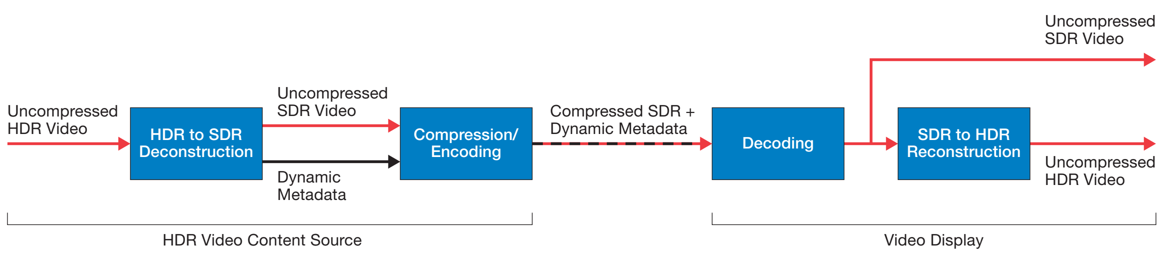

Figure 13: SL-HDR1 deconstruction, streaming, and reconstruction process.

HDR Glossary

Arc minute – The angle subtended by 1/60 of one degree, or alternatively, 1/21600 of a circle. Due to the physical structure of the eye and the size and arrangement of photoreceptor cells in the retina, 1 arc minute is the generally accepted limit of human visual acuity.

CEA-861.3 – A standard released by the Consumer Electronics Association (now known as the Consumer Technology Association – CTA) to specify HDR static metadata exchange using InfoFrames and EDID. The HDMI 2.0a and DisplayPort 1.4 specifications cite CEA-861.3 mechanisms to support HDR.

D65 – Reference white point for the BT.709, DCI-P3, and BT.2020 color gamuts. D65 corresponds to a color temperature of 6500 K and has coordinates of xW = 0.3127, yW = 0.329 on the CIE chromaticity diagram.

DCI-P3 – Color space specified by the Digital Cinema Initiative and standardized in SMPTE 428-1. It covers 45.5% of the CIE color gamut.

Dolby Vision – A proprietary high dynamic range video format developed by Dolby Laboratories for video content creation, distribution, and playback.

Gamma – A video display EOTF characterized by a power law relationship between the on-screen luminance and the input video signal where: Luminance = $(\text{Input Signal})^{\text{gamma}}$

HDR10 – A high dynamic range media profile defined by the Consumer Electronics Association for IP, HDMI, or other video delivery sources to incorporate SMPTE ST 2084 EOTF; 4:2:0 chroma subsampling for compressed video; 10 bits per color; ITU-R BT.2020 color gamut; and SMPTE ST 2086, MaxFALL, MaxCLL metadata.

Hybrid Log Gamma (HLG) – A high dynamic range video format jointly developed by the BBC and NHK to be backward compatible with standard dynamic range displays. HLG is not natively compatible with other HDR formats such as HDR10 and Dolby Vision. HLG streamlines live HDR broadcast operations by eliminating the need for additional metadata required by HDR10 and Dolby Vision.

ITU-R BT.709 – A set of parameter values for high definition television systems for production and international program exchange recommended by the International Telecommunication Union. Defined video parameters include:

- Resolution: 1920x1080, progressive or interlaced
- Color depth: 8 or 10 bits per color
- Frame rate (Hz): 60, 59.94, 50, 30, 29.97, 25, 24, 23.98
- Chroma sampling: 4:4:4 or 4:2:2
- Primary colors and white point coordinates that cover 35.9% of the CIE color gamut:
  - Red: $x_R = 0.640$, $y_R=0.330$
  - Green: $x_G = 0.300$, $y_G = 0.600$
  - Blue: $x_B = 0.150$, $y_B = 0.060$
  - White: $x_W = 0.3127$, $y_W = 0.329$

ITU-R BT.2020 – A set of parameter values for ultra-high definition television systems for production and international program exchange recommended by the International Telecommunication Union. Defined video parameters include:

- Resolution: 3840x2160 or 7680x4320
- Color depth: 10 or 12 bits per color

- Frame rate (Hz): 120, 119.88, 100, 60, 59.94, 50, 30, 29.97, 25, 24, 23.98
- Chroma sampling: 4:4:4, 4:2:2, or 4:2:0
- Primary colors and white point coordinates that cover 75.8% of the CIE color gamut:
  - Red: $x_R = 0.708$, $y_R=0.292$
  - Green: $x_G = 0.170$, $y_G = 0.797$
  - Blue: $x_B = 0.131$, $y_B = 0.046$
  - White: $x_W = 0.3127$, $y_W = 0.329$

MaxCLL – Maximum content light level – video stream metadata that indicates the highest luminance value of any pixel in the entire content stream.

MaxFALL – Maximum frame average light level – video stream metadata that indicates the highest average luminance value of any frame in the entire content stream.

Perceptual Quantizer (PQ) – A video display EOTF optimized for high dynamic range with maximum luminance of 10,000 nits. It was initially developed by Dolby Laboratories and has been standardized as SMPTE ST 2084.

Retina Display – A video display whose pixel structure cannot be discerned by someone with normal human visual acuity when viewed at a specified distance.

SL-HDR1 – A high dynamic range video streaming system jointly developed by STMicroelectronics, Philips International B.V., CableLabs, and Technicolor R&D France and standardized as ETSI TS 103 433. SL-HDR1 involves deconstruction of HDR video to SDR video plus dynamic, content-dependent metadata. The results of the deconstruction are encoded and transported as a standard HEVC or AVC stream, which can be decoded by HDR-capable receivers and is also backward compatible with SDR receivers.

Transfer Function – The relationship between a system's output signal and its input signal. The transfer function characterizes system behavior and defines how the system transforms the input signal into the output signal. A video broadcast system may be characterized by a series of transfer functions:

- OOTF – Opto-Optical Transfer Function, the end-to-end relationship between an image viewed at a video display and the light that was captured by a camera. The OOTF can be further separated into the camera's transfer function (OETF), signal processing and artistic adjustments performed during production and distribution, and the display's transfer function (EOTF).

- OETF – Opto-Electronic Transfer Function, the relationship between a camera's input (captured light) and the camera's electronic output signal.

- EOTF – Electro-Optic Transfer Function, the relationship between a video display's input signal and the on-screen luminance generated by the display.