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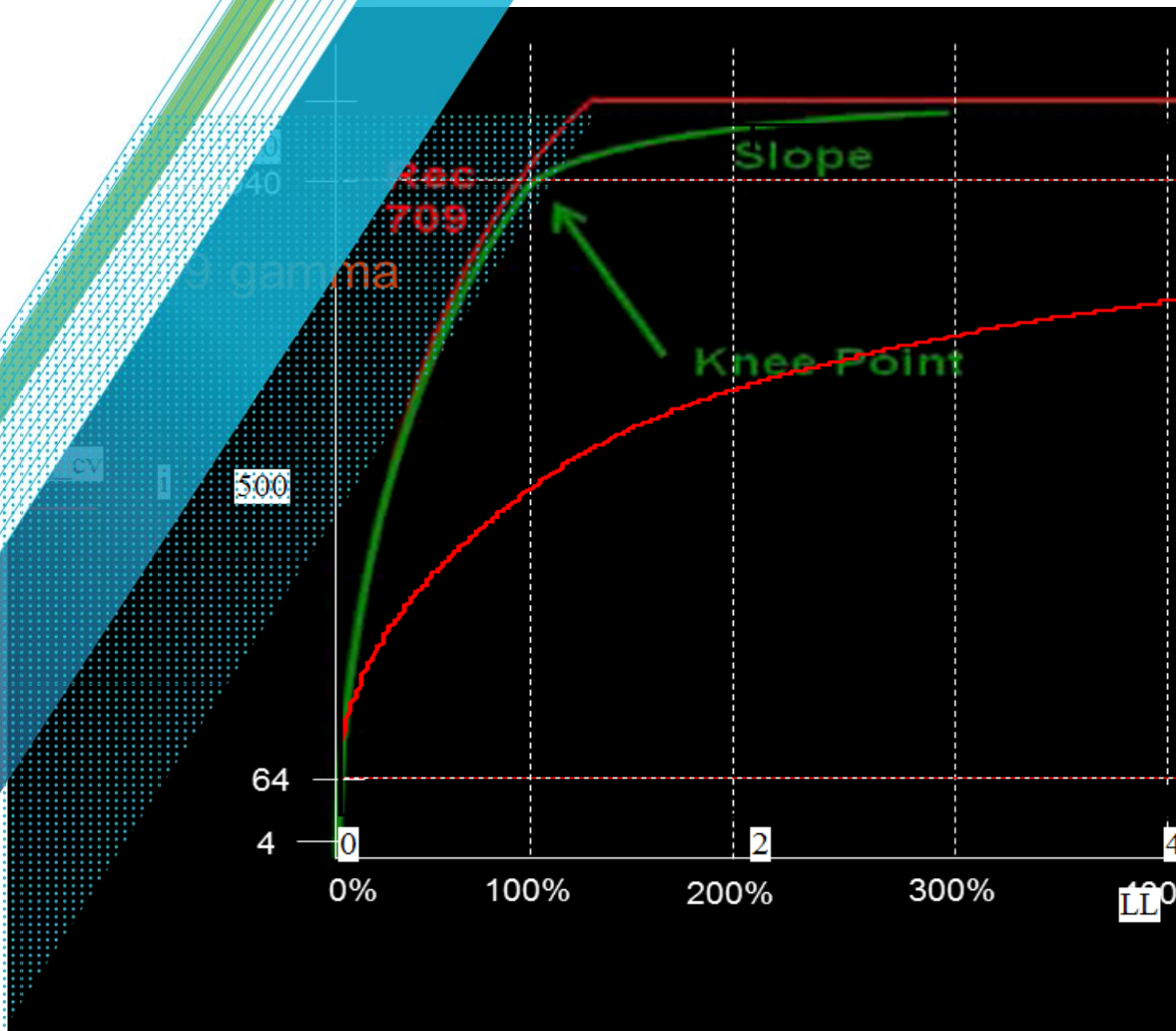
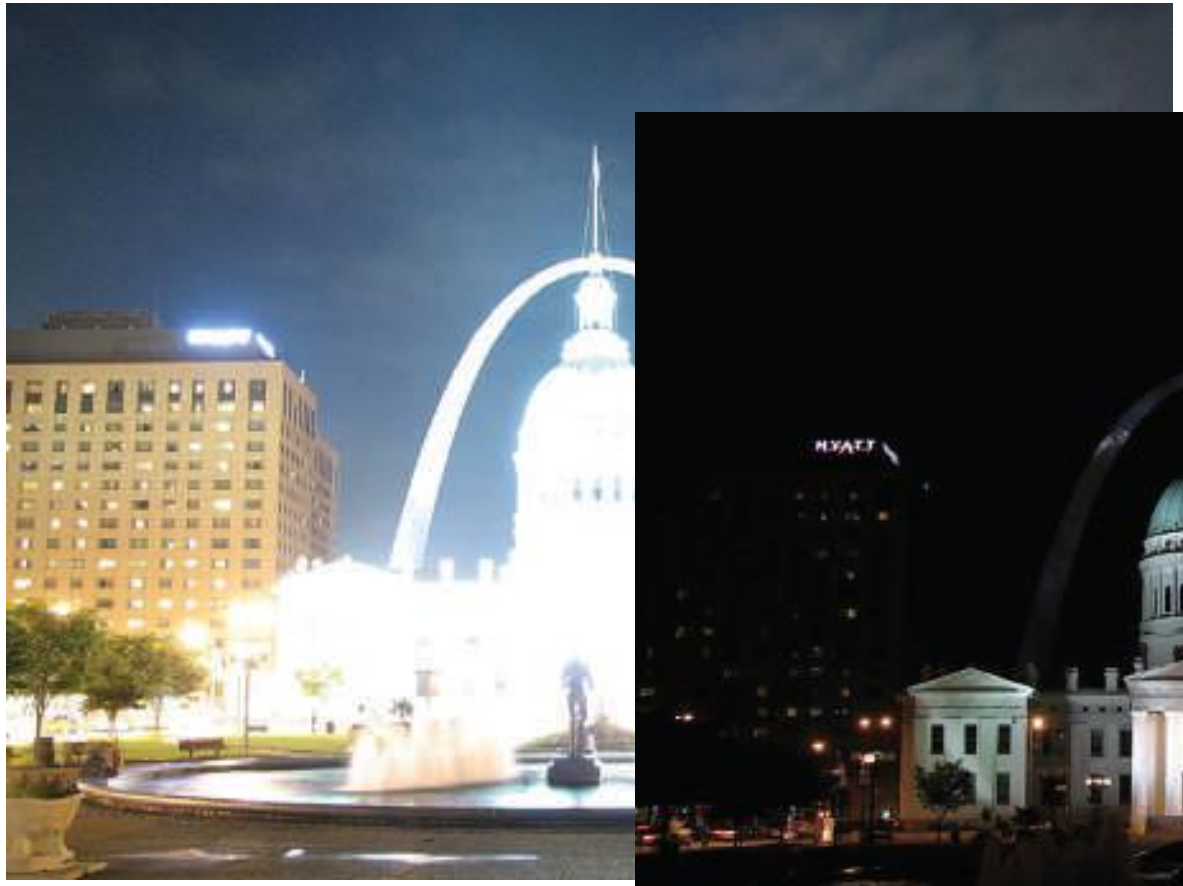
HDR, Who's, How ……

Steve Holmes

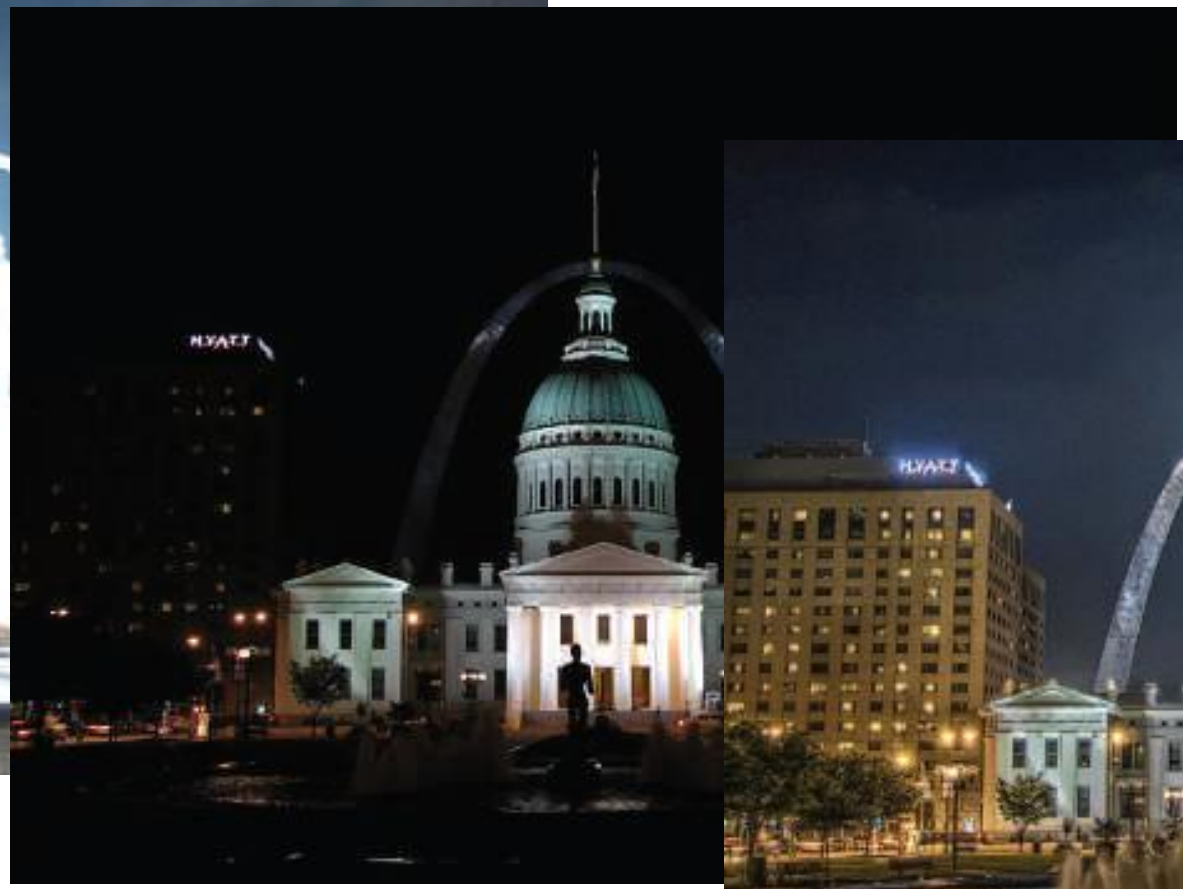


DSLR HDR

Over exposed



Under exposed



Combined

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HDR what is it?

- There are two parts to High Dynamic Range (HDR) the Monitor (Display) and the Camera (Acquisition)

- In the Monitor it is trying to get the display to have the range of the material presented to it. Not just making things brighter with no more resolution of what is being shown. But brighter with more resolution.
- In the Camera it is trying to get many more ‘F’ stops, wider dynamic range with the data for that range.
- SDR is Standard Dynamic Range
- Sometimes there is a tendency to try and raise the diffuse white point to high and the pictures look washed out and too bright.

HDR is not High brightness

- Its **High Dynamic Range**

High brightness (high contrast)

High Dynamic Range

Not just Brighter, but better, more depth (data) in the extra brightness.
HDR done incorrectly looks really Bad (Left Pic).

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Terms

- 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, Rec.709, Rec.2020)
- PQ – Perceptual Quantizer Transfer Function 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, PQ, Dolby Vision dynamic metadata
- HDR10 – 10-bit HDR using BT.2020, PQ and 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

Standards

- ITU-R BT.709
  - AKA Rec709 standardizes the format of high-definition television, having 16:9 (widescreen) aspect ratio
- ITU-R BT.2020
  - AKA Rec2020 defines various aspects of ultra-high-definition television (UHDTV) with standard dynamic range (SDR) and wide color gamut (WCG), including picture resolutions, frame rates with progressive scan, bit depths, color primaries
- 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), frame rate, chroma subsampling, color space
- ST 2084
  - Specifies an EOTF characterizing high-dynamic-range reference displays used primarily for mastering non-broadcast content. This standard also specifies an Inverse-EOTF derived from the EOTF (the Barton PQ curve)
- 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. The metadata is specified as a set of values independent of any specific digital representation.
- 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 (HDR) 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 use a logarithmic curve.

HDR Technologies

- From what I'm seeing there are four basic different types of signal options
- ST2084 curve No Meta Data UHD Alliance
- ST 2084 with Static Meta Data Ultra HD Blu-ray HDR10
- ST 2084 with Dynamic Metadata for Color Transform DMCVT ST 2094
  - Dolby (Parametric Tone Mapping)
  - Philips (Parameter-based Color Volume Reconstruction)
  - Technicolor (Reference-based Color Volume Remapping)
  - Samsung (Scene-based Color Volume Mapping)
- HLG defines a nonlinear transfer function in which the lower half of the signal values use a gamma curve (SD & HD) and the upper half of the signal values use a logarithmic curve. HLG is backwards compatible with SDR.

Light Levels

- In measuring the light output of a TV, Monitor or screen we use the measurement unit Nit.
  - One candela per square meter (cd/m^2).
  - From the Latin (nitere = to shine)

- In lighting, the nit is a unit of visible-light intensity, commonly used to specify the brightness of a cathode ray tube or liquid crystal display computer display. One nit is equivalent to one candela per square meter (**cd/m^2**). The candela, formerly called candlepower, is approximately the amount of light emitted by a single common tallow candle.
- In Rec709 100% white (700mV) is reference to 100 Nits.

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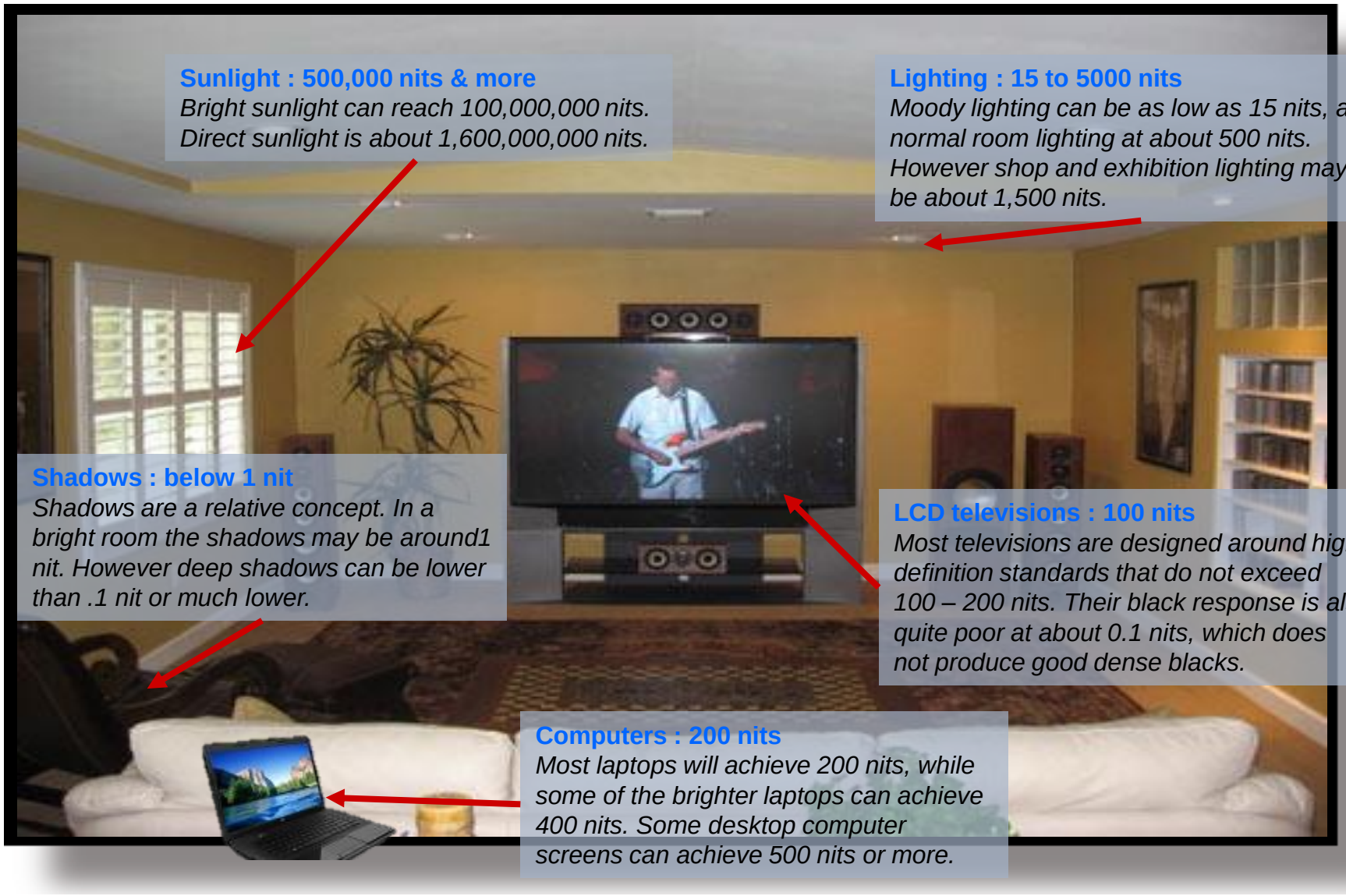
Light Levels



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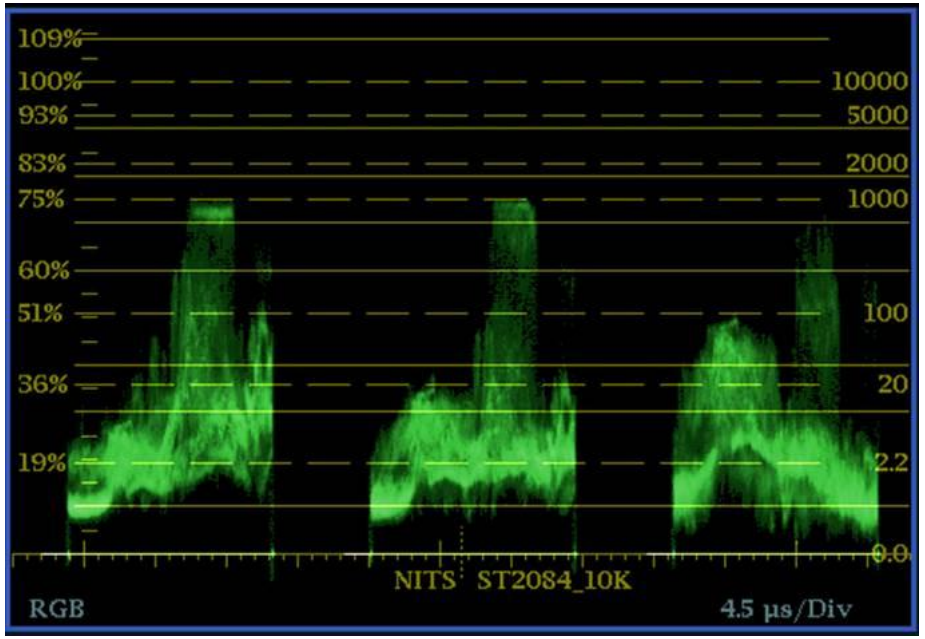
No Tone Mapping – UHD Alliance

- Very much like HD Rec 709
- The Monitor has Fixed Levels
- Expects the content to be at the proper levels per scene as we do with 709
- Levels based on Grade 1k, 2K, ect., the monitor must matched the grade manually



Fixed Grade at 1K nits in this case

Monitor must be able to do a 1K grade

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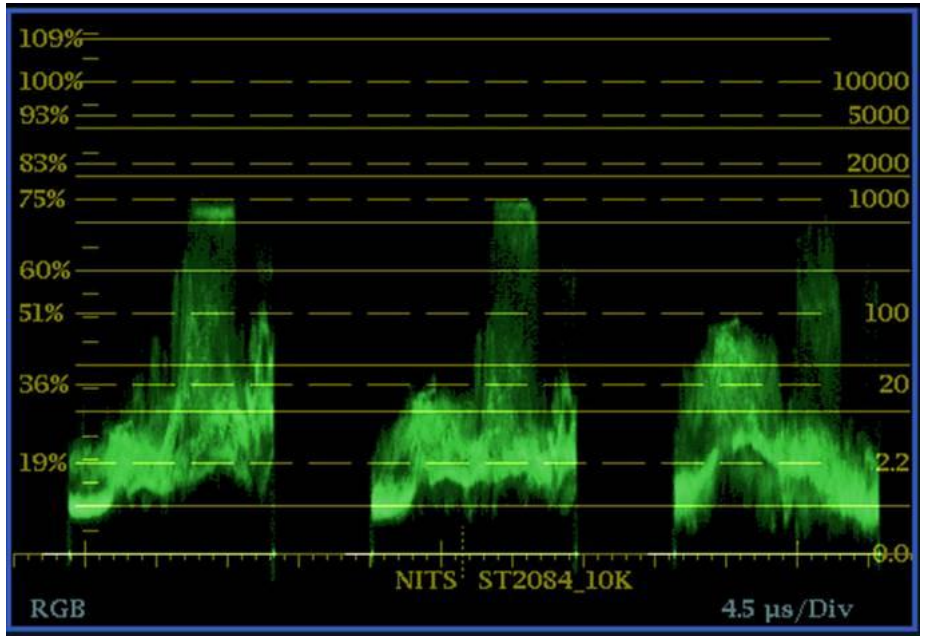
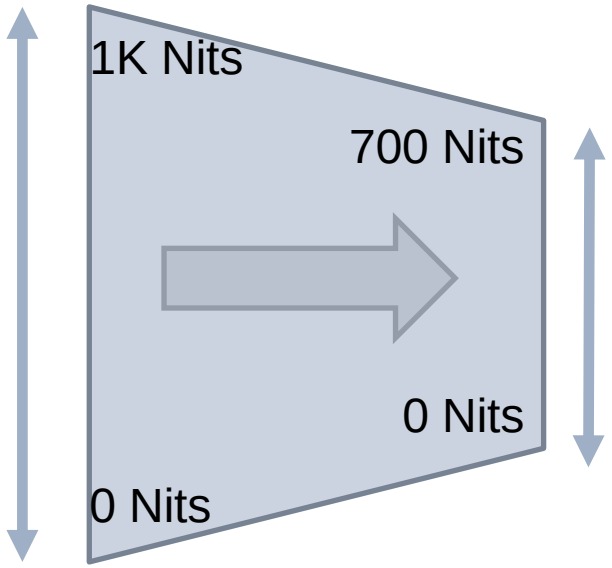
Static Tone Mapping

- Expects the content to be at the proper levels per scene as we do with 709
- Metadata is sent to the Monitor that shows the Grade of the entire file
- If the file was a 1K Nit Grade but the Monitor can only do 700 Nits the monitor can adjust / Scale the input Video to fit its Brightness range.



Fixed Grade at 1K nits in this case



Monitor will Scale the input to its Nit range

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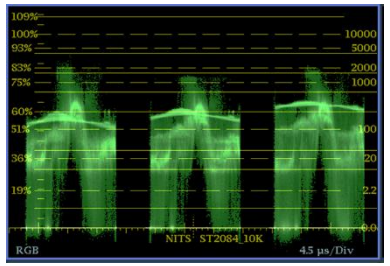
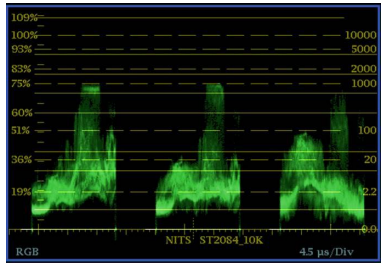
Dynamic Tone Mapping

- Color transforms optimized for each scene, and each Monitor
- ST 2094 Standardizes HDR color transform technologies from several companies
- Color and Image information is carried in Metadata
- Select where and when to apply the Metadata information



Mastering display color primaries:
R:x=(0.708)y=(0.292)
G:x=(0.17)y=(0.797)
B:x=(0.131)y=(0.046)
White point:x=(0.3127)y=(0.329)
Mastering display luminance:
Min:0cd/m2,
Max:1000cd/m2
Maximum Content Light Level(MaxCLL):800cd/m2
Maximum Frame-Average Light Level(MaxFALL):400cd/m2
Color primaries:Rec. ITU-R BT.2020
Transfer Characteristics:SMPTE ST 2084
Matrix Coefficients:ITU-R BT.2020 non-constant luminance system

METADATA



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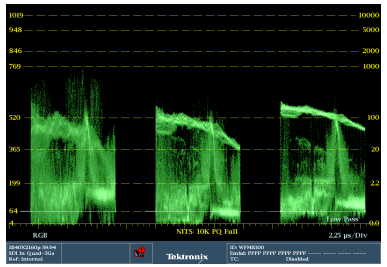

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METADATA

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Who's HDR? Dolby Vision or HDR10 (US)

HDR FROM A DISPLAY PERSPECTIVE all use ST2084 except when doing HLG

- Dolby Vision
  - Philips, Hisense, Toshiba, Vizio and LG
- HDR10 only
  - Sony
  - Samsung
  - LG
  - Panasonic

LG now supporting Dolby Vision also

- Well with Dolby and the TV giants, someone said "I smell format war."

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Electro-Optical Transfer Function (EOTF)

- HDR provides a means by which to describe and protect the content creator's intentions via metadata. It contains in essence a language used by the content creator to instruct the decoder. HDR provides metadata about how content was created to a display device in an organized fashion such that the display can maximize its own capabilities. As displays evolve, HDR will allow existing devices to always make a best effort in rendering images rather than running up against unworkable limitations.
- A formula called the electro-optical transfer function (EOTF) has been introduced to replace the CRT's gamma curve. Some engineers refer to EOTF more simply as perceptual quality, or PQ. Whatever the name, it offers a far more granular way of presenting the luminance mapping according to the directions given by the content creator. EOTF is a part of the High Efficiency Video Coding (HEVC) standard.

BACKWARDS COMPATIBILITY

- Settling on an approach that doesn't require the replacement of encoders/decoders is very important to some pay TV companies, distributors and device manufacturers. Dolby Vision, Technicolor, Philips and BBC/NHK are all backwards compatible. In a backwards compatible approach when an SDR television receives the video signal, the HDR metadata simply is ignored by the set-top boxes or display.
- However, not all prospective customers of HDR care about backwards compatibility. Backwards compatibility is less of an issue in some distribution ecosystems, such as over-the-top (OTT) and Post. A situation could arise, therefore, in which supporting HDR would require the change out of encoders, decoders and cable set-top boxes. Non backwards-compatible approaches no doubt will lead to significant expense to various members of the ecosystem because maintaining two sets of content (SDR and HDR) may become necessary.

Display Curves (Gamma)
Display Color Space (709, P3, 2020)

What is Gamma?

- **Gamma Q&A**
  - CRT Defect? It is caused by the voltage to current grid-drive of the CRT and not the phosphor. (i.e. a current-driven CRT has a linear response)
  - Needed to match Human Visual Response? Not really true if display matches scene!
  - Can I adjust gamma? CRT is black-level sensitive power-law. Light power = (V + black-level)^{gamma} so the room light or Black-level adjustment dramatically changes gamma.
  - Gamma for a CRT fairly constant at about 2.4 to 2.5 but what about flat panel displays? BT.1886 says all displays should be calibrated to 2.4. Black-levels can track room lighting with auto-brightness (began in early 70's). But Changes Gamma.
  - Why not get rid of gamma power-law? For some time now, we have. Cameras do not need to be set for BT.709 gamma. But, for current HD SDR displays, even with BT.2020 colorimetry, BT.1886 applies. BT.1886 says all displays should be calibrated to 2.4. Black-levels can track room lighting with auto-brightness (began in early 70's). But Changes Gamma.

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Image reproduction using video is perfect if display light pattern matches scene light pattern.

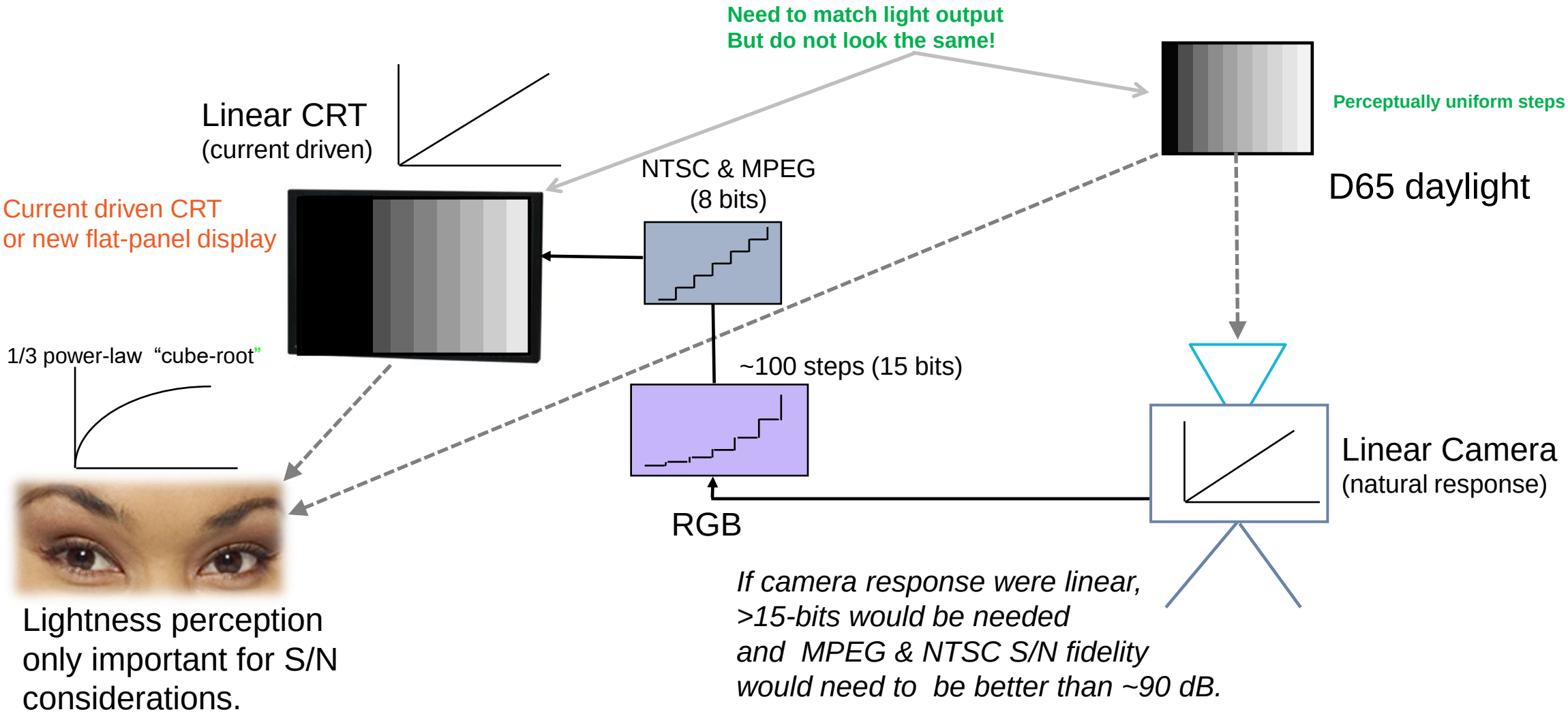

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Image reproduction using video is perfect if display light pattern matches scene light pattern.

Need to match light output.
Look the same with only 7-bits

CRT response

What about new flat-panel displays?

~100 steps (7-bits)

1 JND
1 JND
1 JND

D65 daylight light source

1/3 power-law "cube-root"

8-bits

RGB

Thanks to the CRT gamma, we compress the signal to roughly match human perception and only 7 bits is enough!

Lightness perception only important for S/N considerations.

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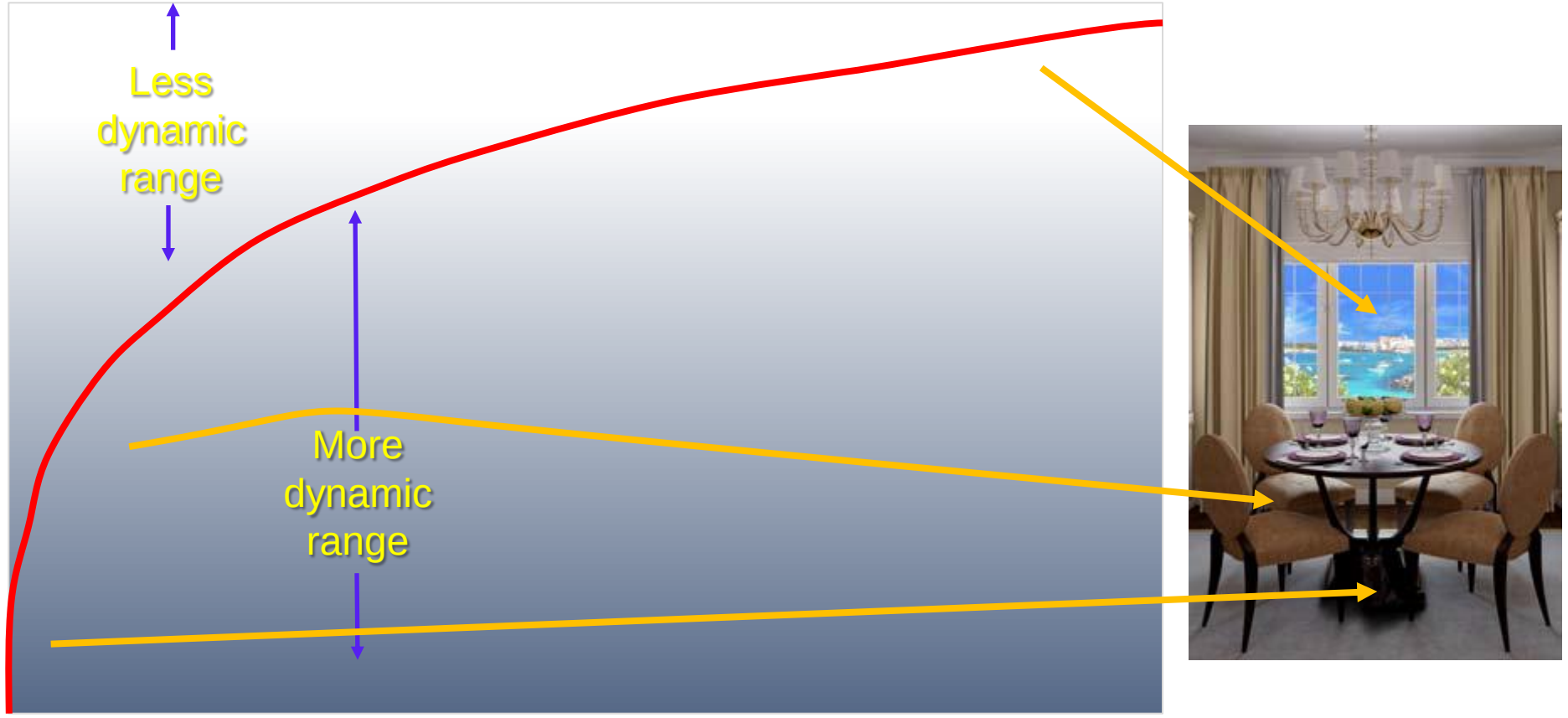
Human Eye Sensitivity

The eye sees change in low light levels much more than in High light levels
So we need to give more bits to the lower light levels than we do to bright areas to improve how we see the blacks.



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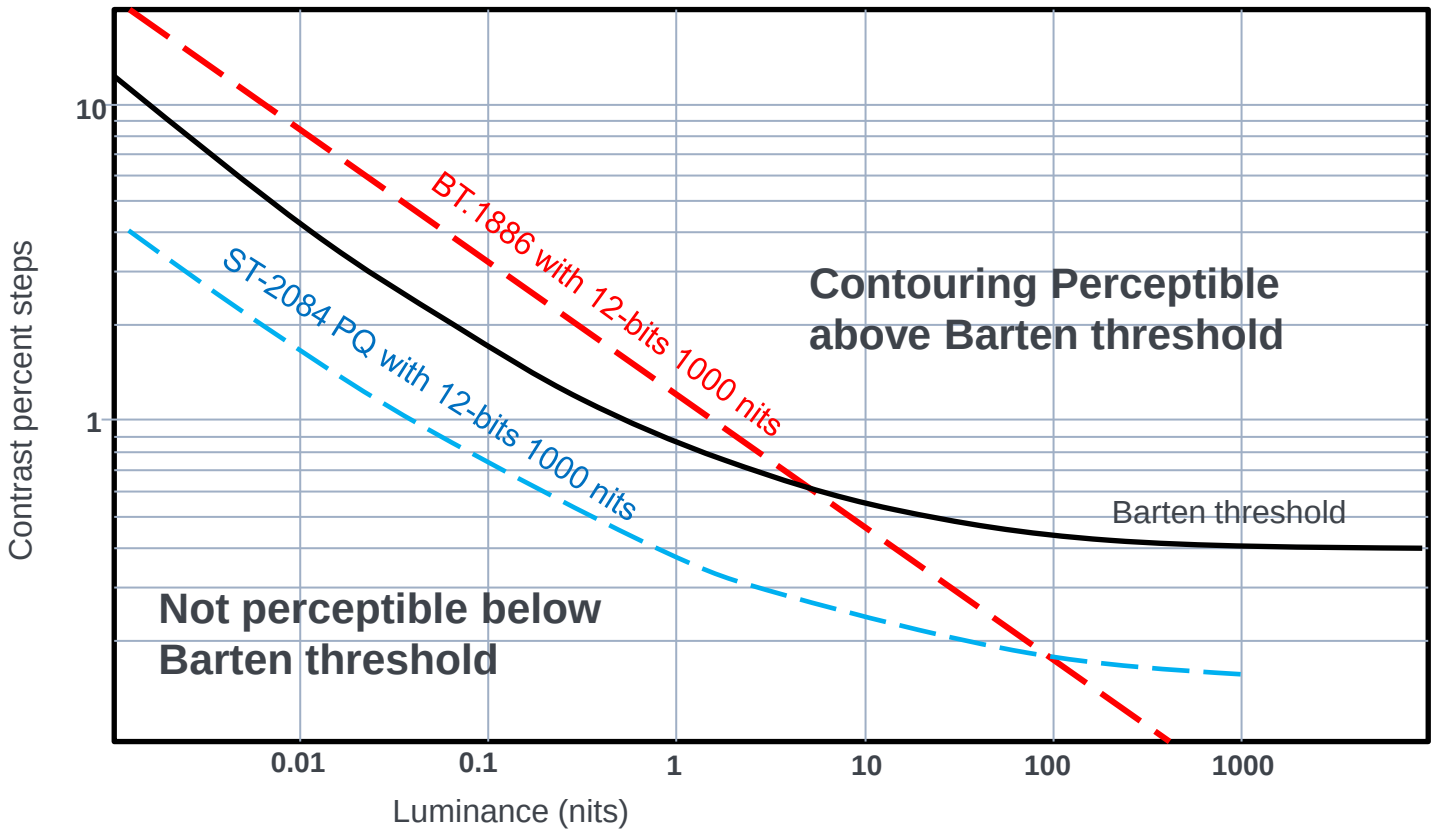
ST.2084 with Perceptual Quantizer for HDR

12-BIT PQ AND REC-1886 COMPARED WITH BARTEN THRESHOLD



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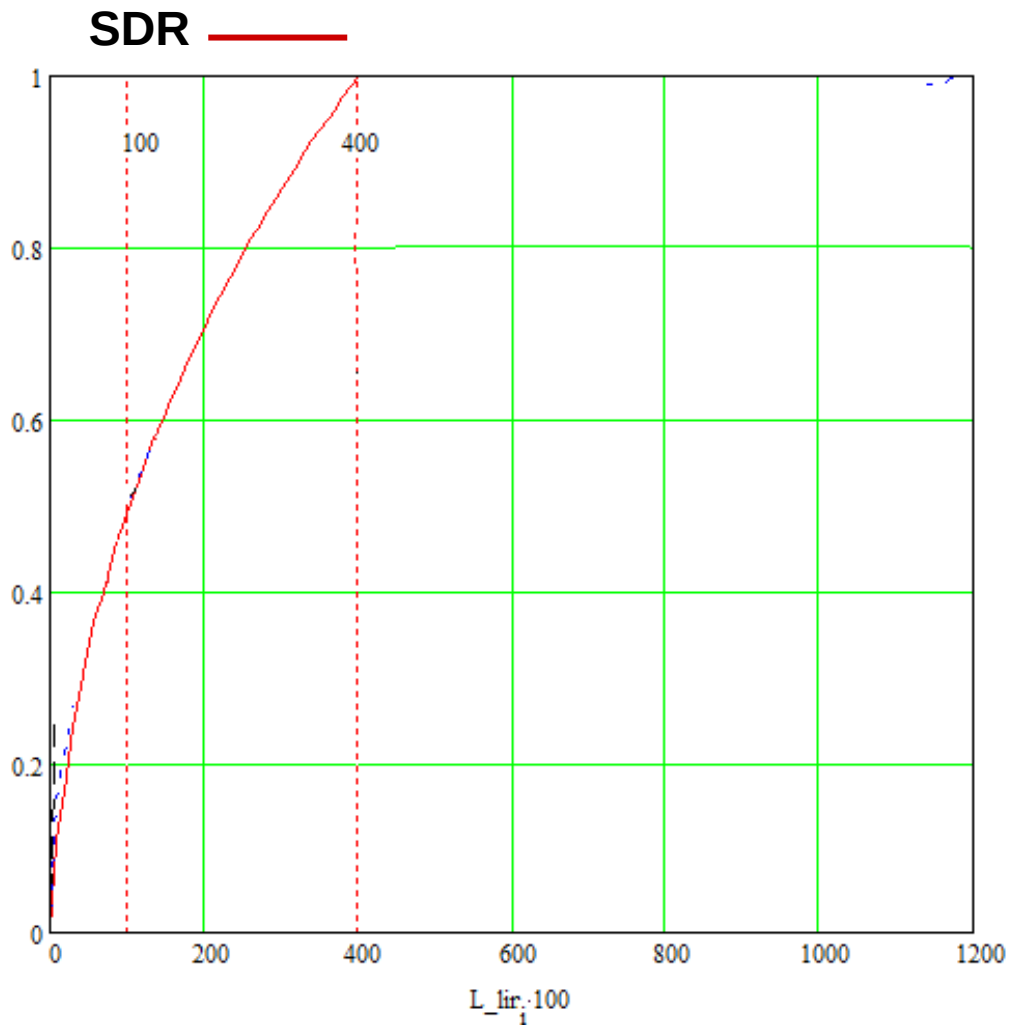
Standard 709 Gamma curve

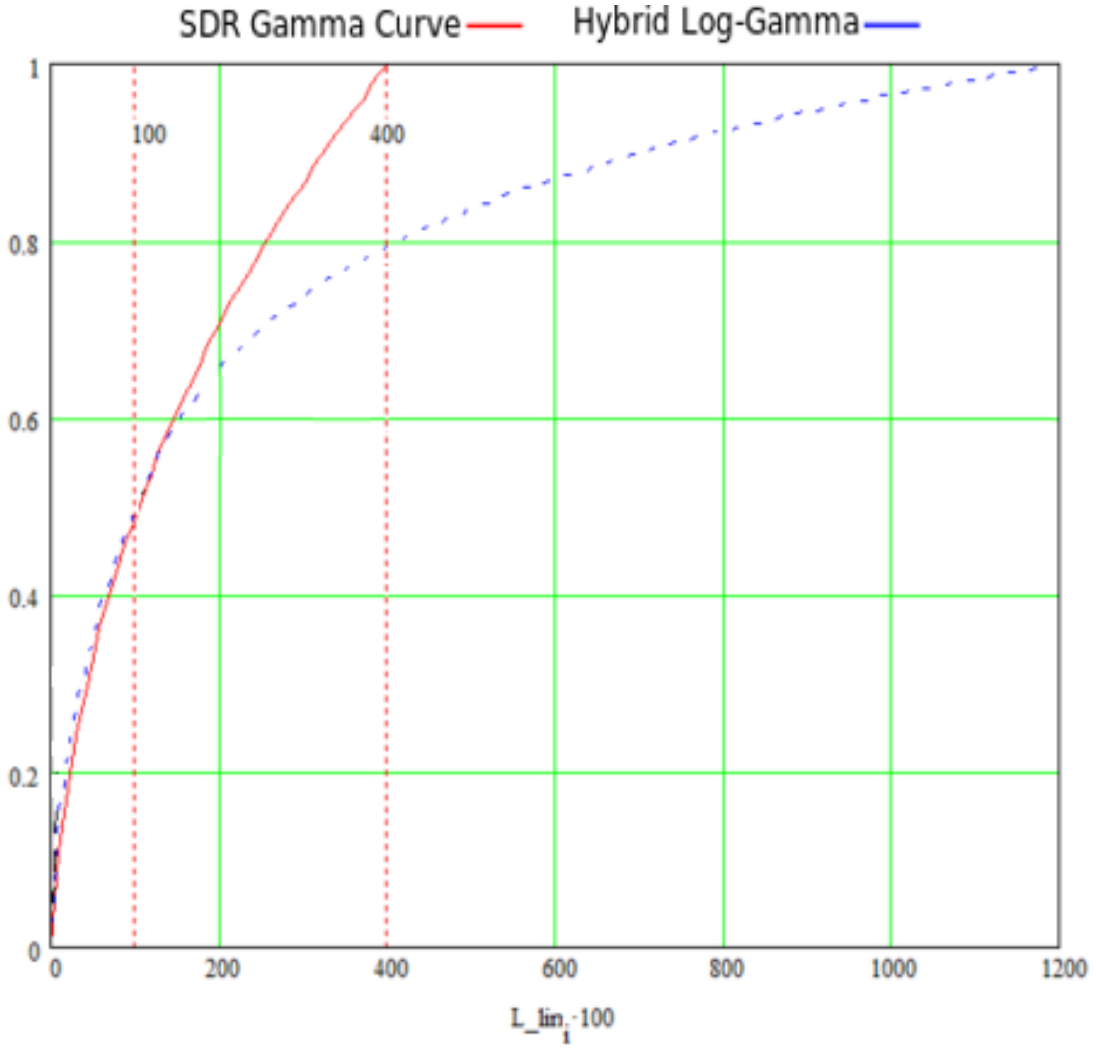
ITU-R BT.1886 SDR

- This Recommendation specifies the reference electro-optical transfer function (EOTF) that the displays used in HDTV program production should follow in order to facilitate consistent picture presentation. The reference EOTF is specified as a simple equation, with exponent function, based on measured characteristics of the Cathode Ray Tube (CRT).



Hybrid Log-Gamma (HLG)

- The ITU-R announced its UHD standard, BT-2020 in October 2015. UHDTV Recommendation BT.2020
- The HDR-TV Recommendation details two options for producing High Dynamic Range TV.
  - The Perceptual Quantization (PQ) ST2084 standard.
  - Hybrid Log-Gamma (HLG) specification supported by the BBC and Japan's NHK. This offers a degree of compatibility with legacy displays by more closely matching the previously established television transfer curves.
- Chart showing a conventional SDR gamma curve and Hybrid Log-Gamma (HLG). HLG uses a logarithmic curve for the upper half of the signal values which allows for a larger dynamic range.



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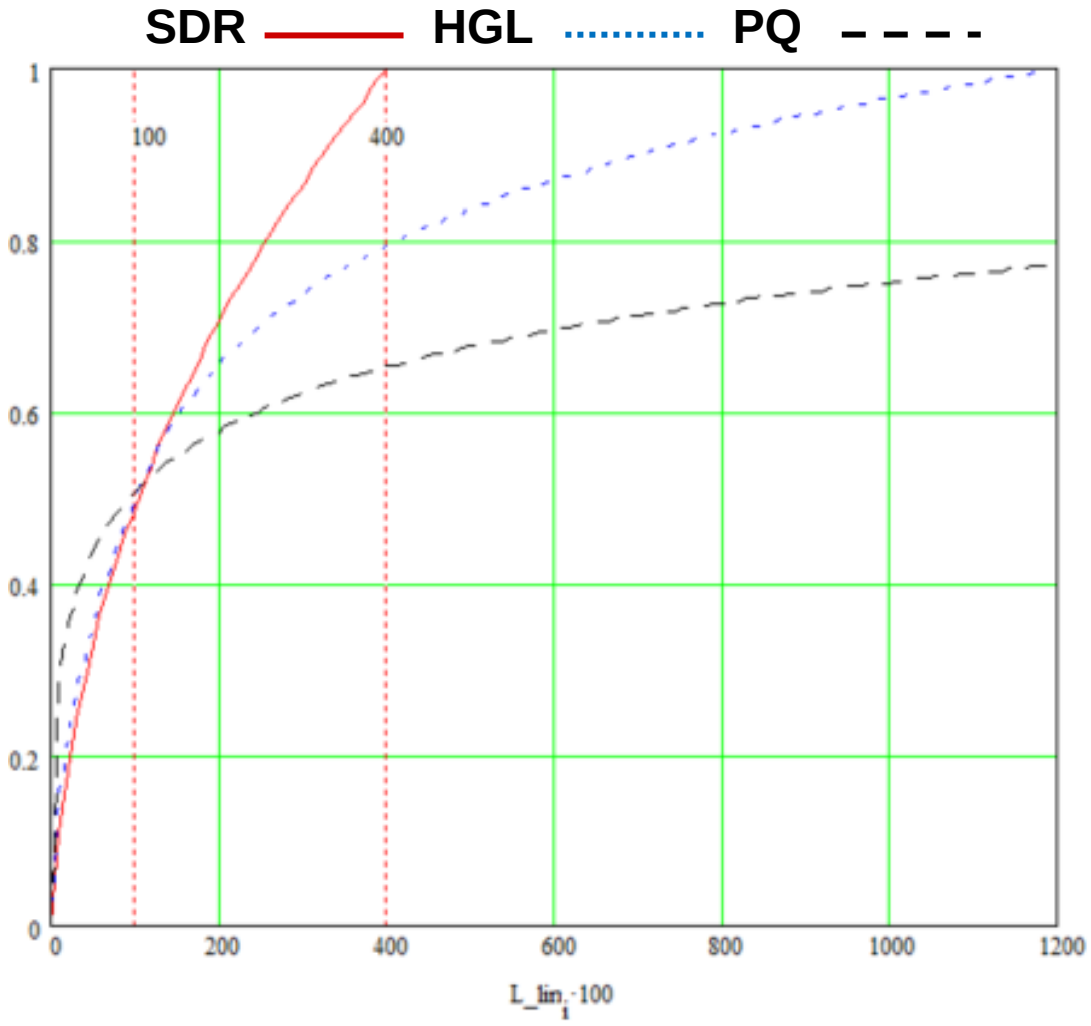
SMPTE 2084

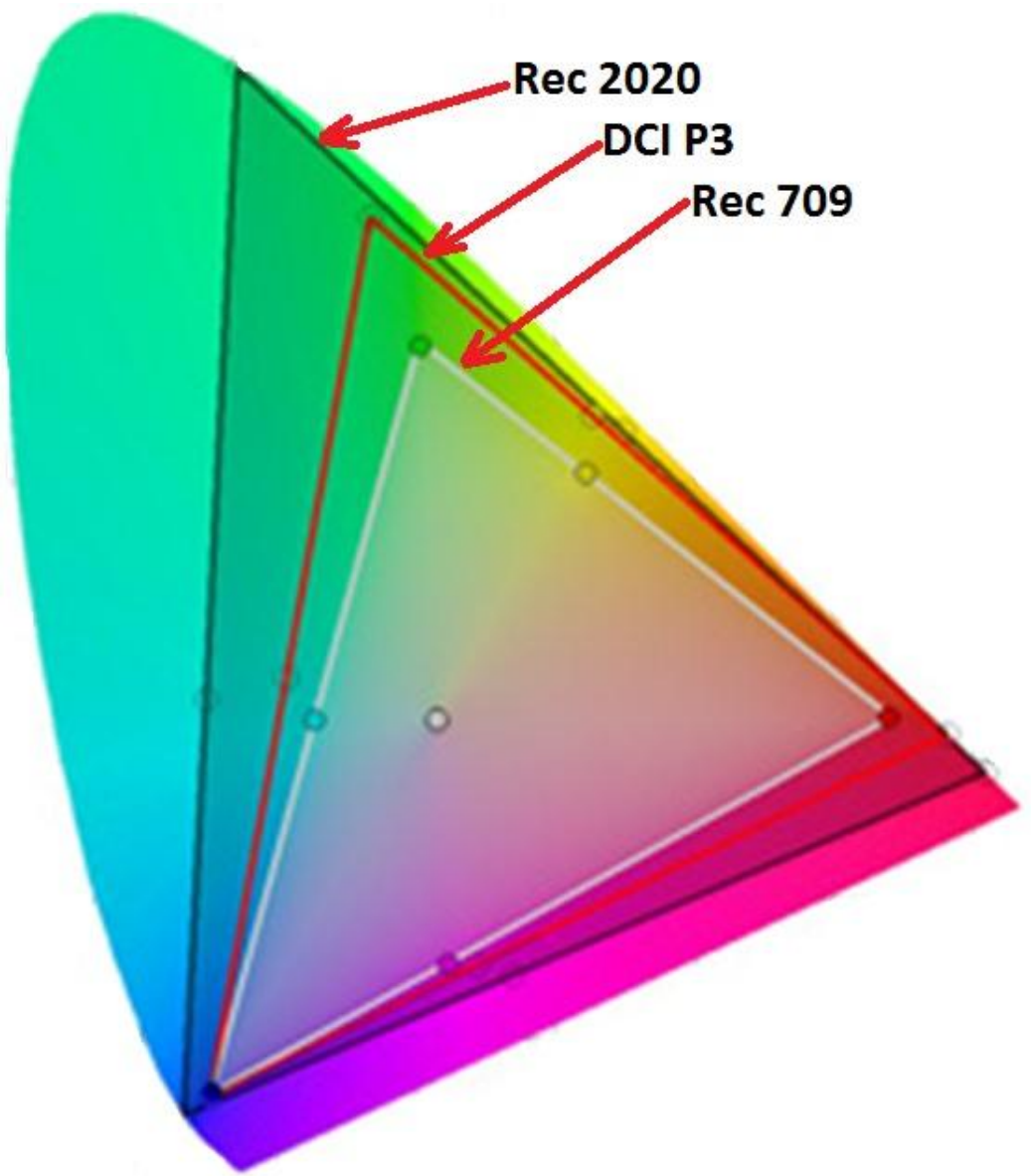
- **AKA Perceptual Quantizer (PQ)**, published by **SMPTE ST 2084**, is a transfer function that allows for the display of HDR video with a luminance level of up to 10,000 Nits (cd/m2) and can be used with the Rec. 2020 color space. Rec-2020 gives more bits to the darker areas. And allows for much brighter specular highlights that do not need as many bits to represent them due to the fact of how the human vision system works.
- Humans see minor changes in the darker areas of a picture much more than we do in brighter areas of a picture.



Color Space DCI, 709, 2020

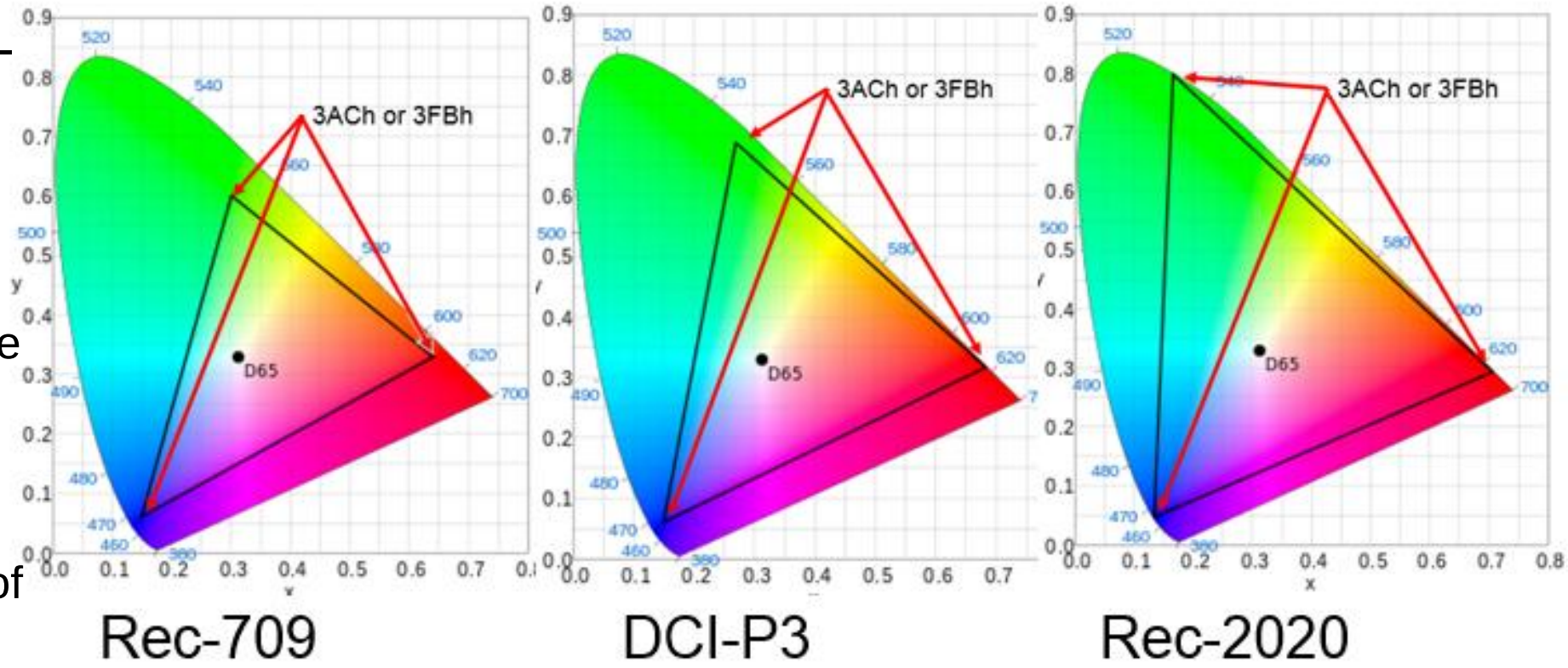
- 4K can use Rec 709, DCI P3, or Rec 2020.

- In SDR Translating from one color space to the next will automatically expand the colors due to the fact that SMPTE 100% levels of 3ACh is 100% of Rec-709, Rec-2020, and DCI-P3.
- It’s the receiver that determines what the code value means.



Code Values for Rec-709, DCI-P3, Rec-2020 colors

- The code Values for the R, G, B primaries are the same for Rec-709, Rec-2020, DCI-P3.
- So a translation between them will expand the colors due to the fact that they use the same code values. (SDR Space)
- R,G,B primaries out of a Generator or any other output is exactly the same for all 3 Color spaces.



Rec-709 DCI-P3 Rec-2020

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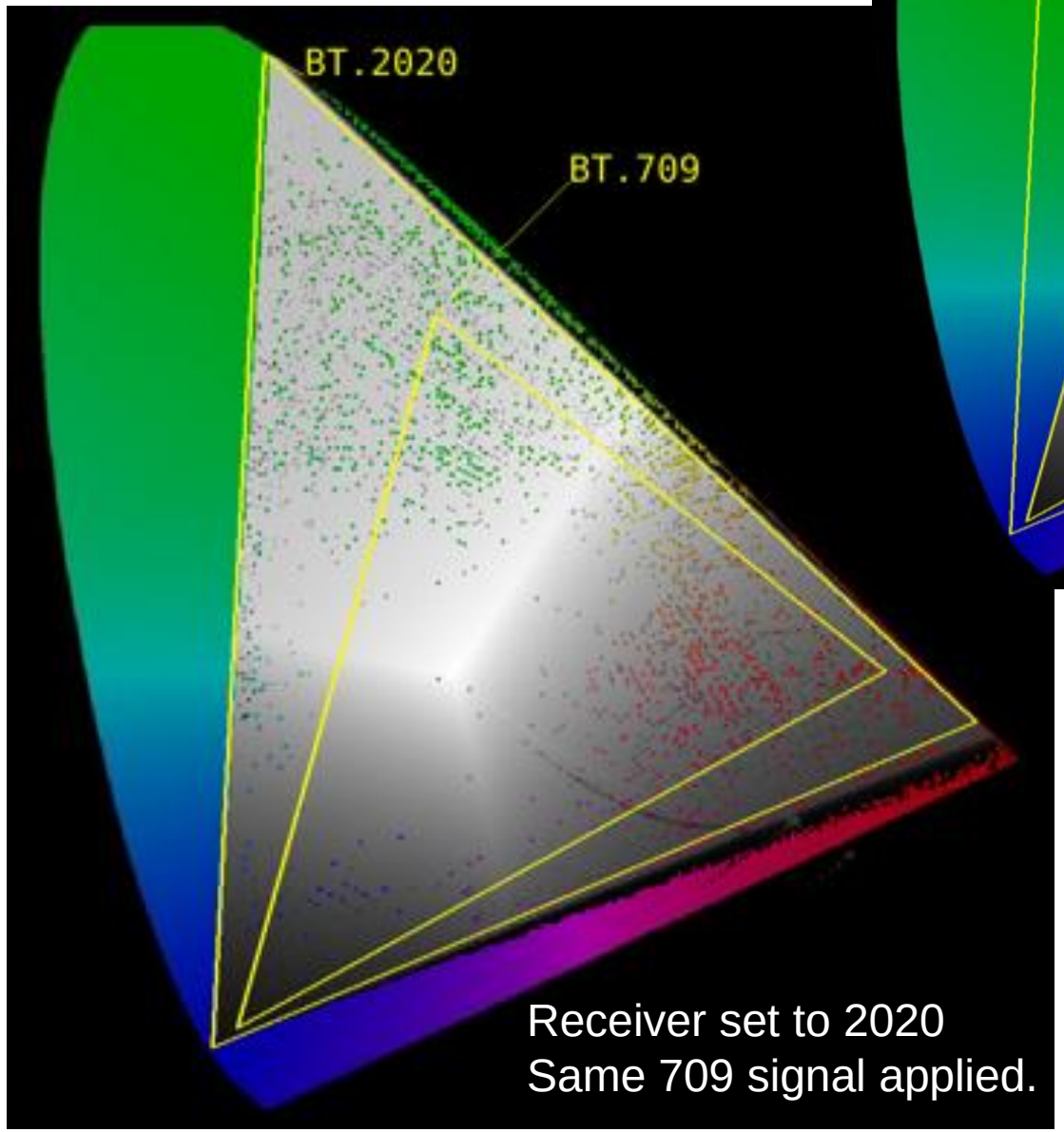
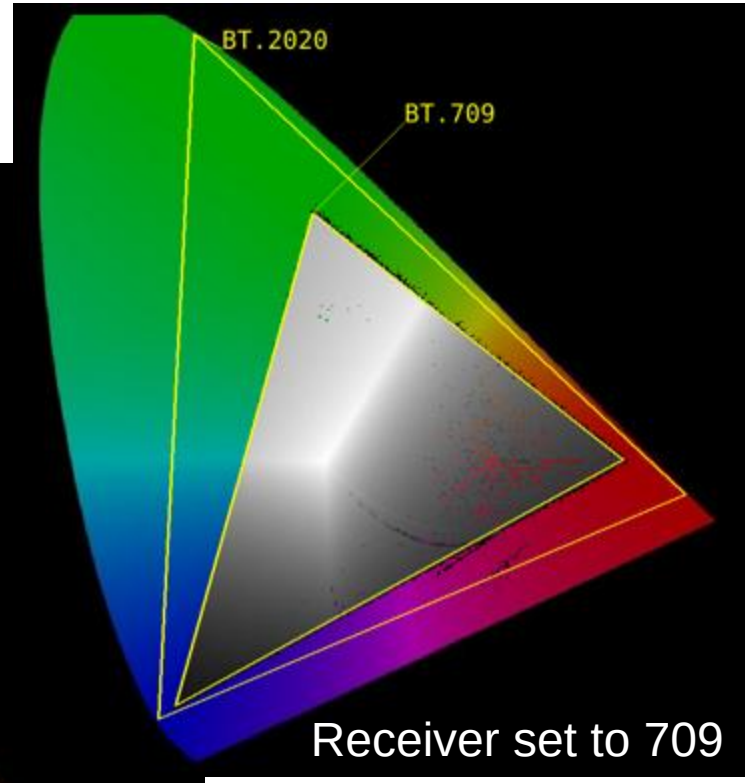
CIE Rec 2020 chart with a Rec 709 signal applied

Some distributors have asked for Rec 2020 color but at P3 levels. You cant just change to P3 color space to do this. It points to the wrong place on the CIE Chart.

You can see that just changing the receivers interpretation just moves the signal to that point. On the SDI signal 100% green is 100% green for all colors spaces. As noted in the previous slide.





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Video Levels

In ITU-R BT.2100 Full is defined as 0d to 1023d for 10 bit, this works just fine for files but SDI has excluded code words for EAV and SAV timing reference signal or TRS. So this gets changed to 4d to 1019d, how the change happens is up to the device outputting the SDI, weather the data gets clipped off or converted to fit this range. That's why on the scope you see 4d as 0 Nits and 1019d as 10,000 Nits in Full.

Full Levels	SDI Levels
▪ Luma & RGB 0d –1023d for 10-bit ▪ Chroma Cb/Cr 0d –1023 for 10-bit ▪ Luma & RGB 0d – 4092d for 12-bit ▪ Chroma Cb/Cr 0d – 4092d for 12-bit	▪ Luma & RGB 64d –940d for 10-bit ▪ Chroma Cb/Cr 64d – 960d for 10-bit ▪ Luma & RGB 256d – 3760d for 12-bit ▪ Chroma Cb/Cr 256d – 3840d for 12-bit

You can set a Luma Gamut alarm for content that goes above a given Nit value to catch specular highlights that go above your target.

Standard levels		Full levels based on 109% =10,000 Nits	
• 1000 Nits	75%	• 1000 Nits	80%
• 2000 Nits	83%	• 2000 Nits	89%
• 4000 Nits	90%	• 4000 Nits	97%

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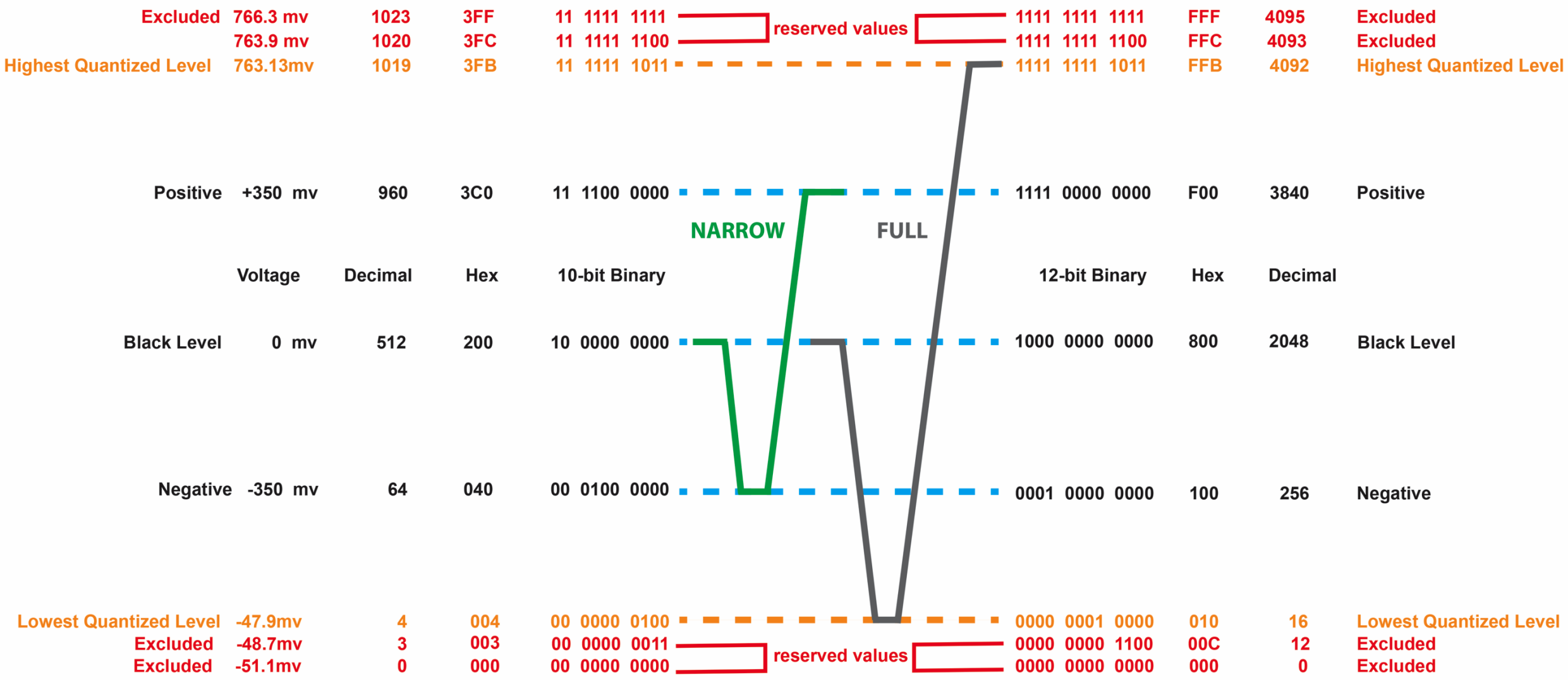
What is Narrow or Full?



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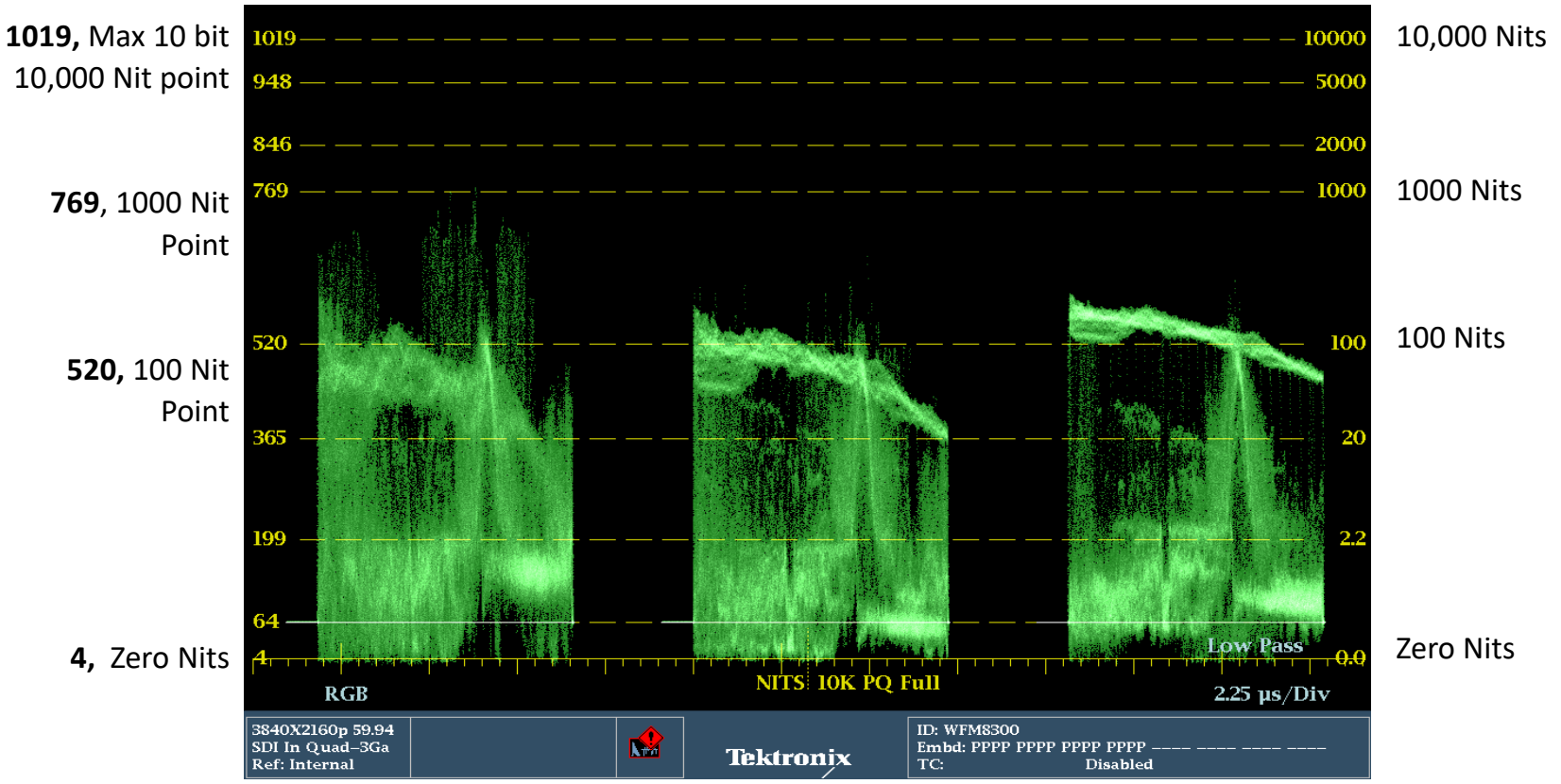
Normal White levels or diffuse white point

- With HDR PQ, there is no agreed upon diffuse white point level. Many are using 100-200 nits as the diffuse white point level, the old 90% reflectance point (100 IRE). Camera operator or colorist/editor must also know what reference monitor will used for grading the content. For example, if a 1000 nit monitor is used for grading, with a diffused white point of 100 nits, white is set at 51% for SMPTE ST 2084 (1K). If a 2000 nit monitor is used, diffuse white is set at 68 %.
- We have the same issue with the different camera formats also. For example a diffused white point of 100 nits is set at 61% for S Log 3, 58% for LogC, and at 63% for C-Log. (More on the next few Slides)

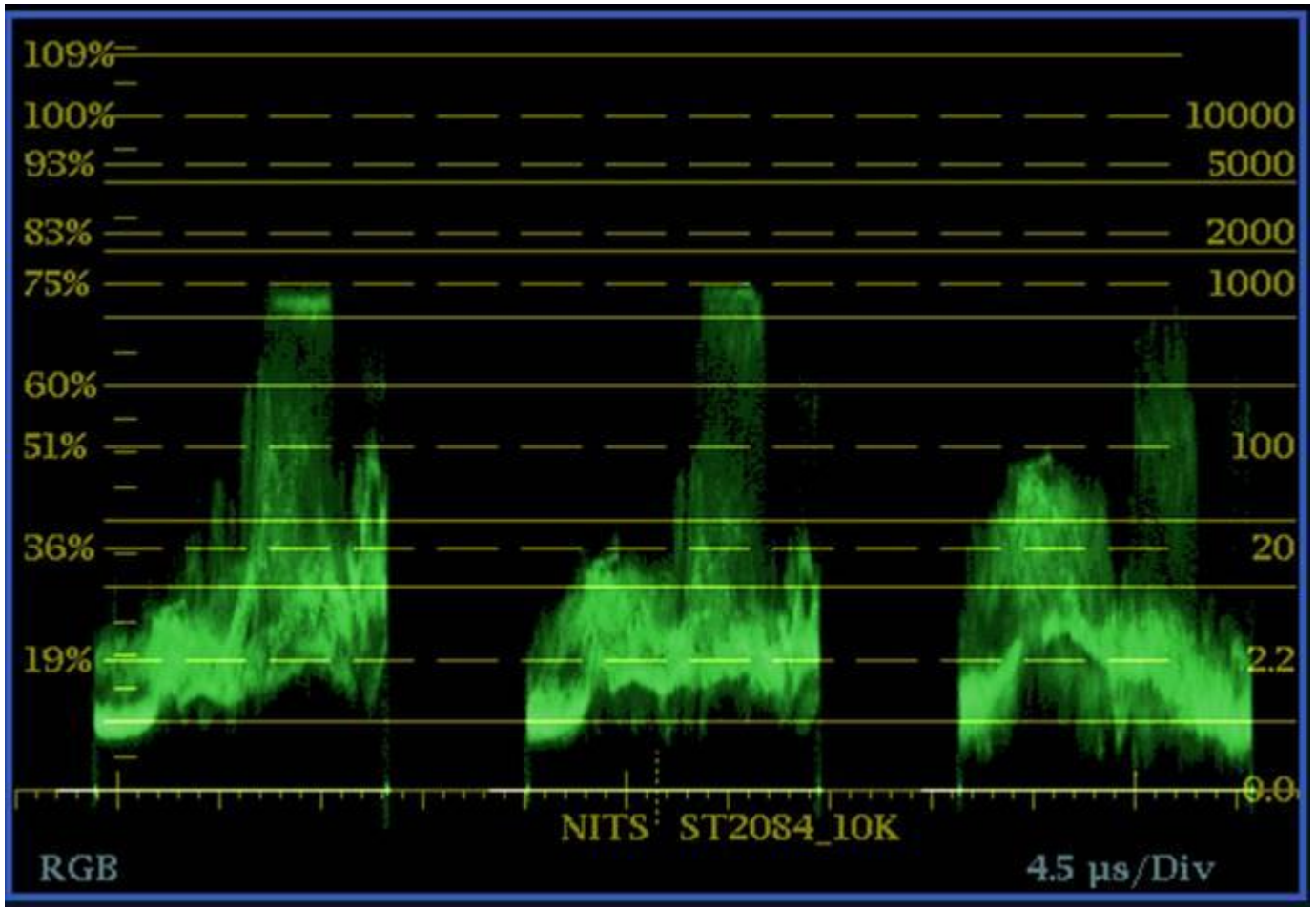
10K PQ with a 1000Nit limit, set to Full range

- If you use the full 10K curve and set your grading to 1000 Nits you will have about the top 25% of the waveform screen not being used. This is normal and correct for this setting. We have implemented both SMPTE SDI levels and Full SDI levels. Below is set to 10K PQ Full range with the Video at 1K grade. The left side of the screen shows the Digital Values, and the right side of the screen shows the Nit Values.

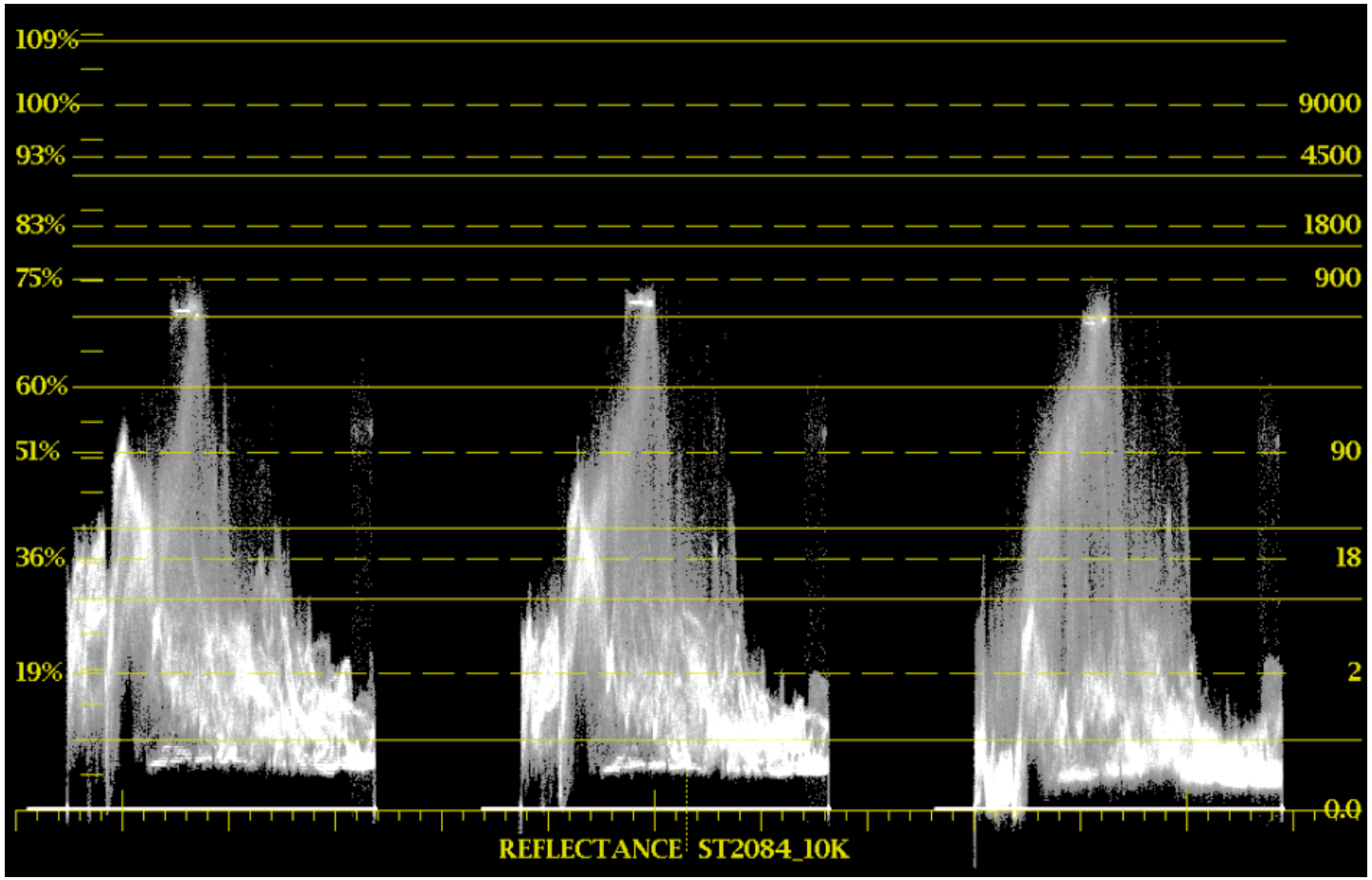


HDR 1 k Grade SMPTE Levels

- The normal reflective Whites are around 100Nits
- The Peek is going to 1000Nits but no higher
- HDR has the blacks stretch and the Whites are compressed



HDR Reflectance View



- 1000 Nits shows up at 900% Reflectance
- The normal reflective Whites are around 100Nits, which is at 90% Reflectance (709 100 IRE)
- We show the 18% Grey point
- We show the 2% Black point

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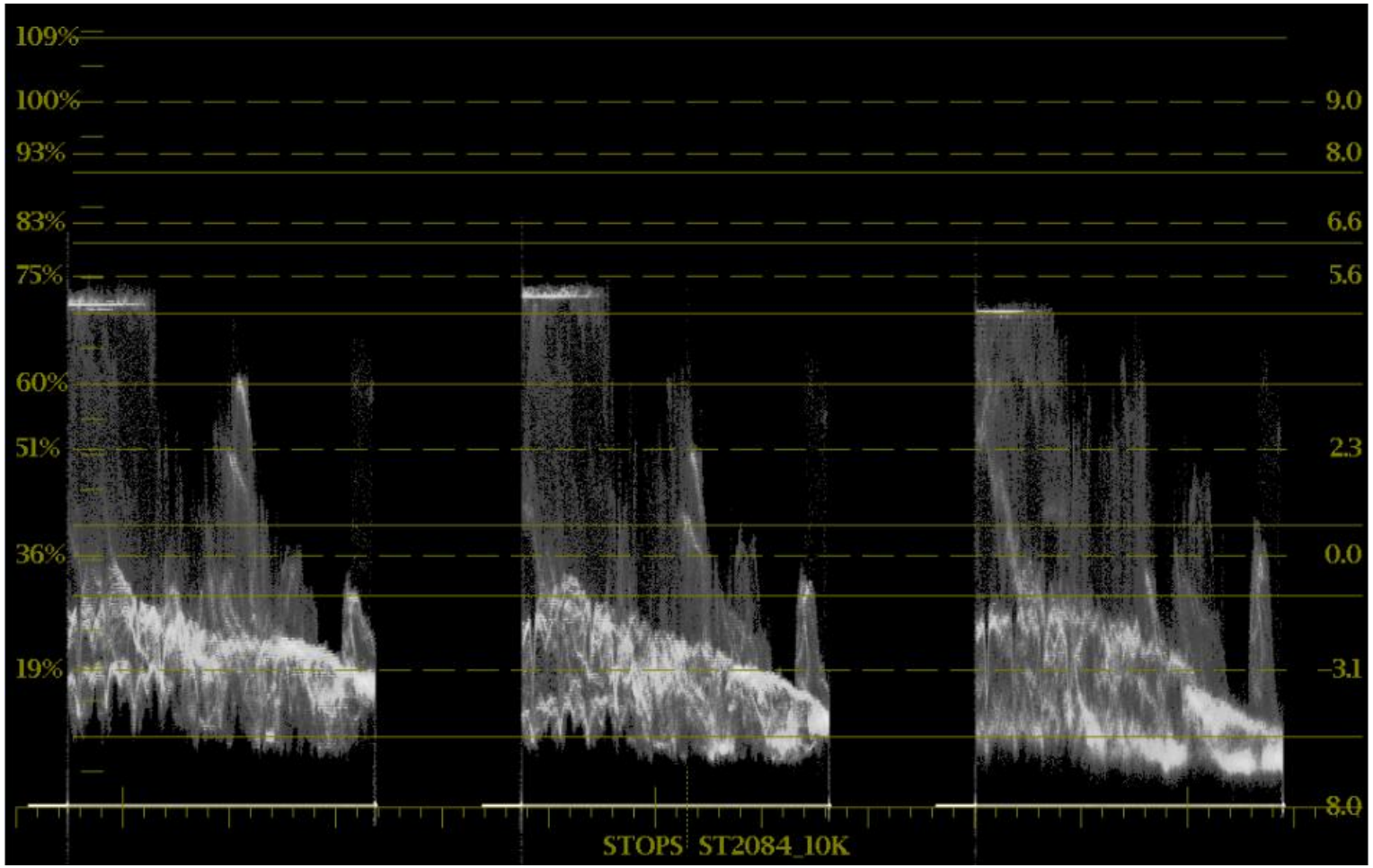
Stop View (relative)



- 1000 Nits shows up at +5.6 Stops above Zero stops at 18% Grey
- The normal reflective Whites are around 100Nits, which is at +2.3 Stops (709 100 IRE)
- We show 0 as the 18% Grey point
- And the 2% Black point at -3.1 Stops

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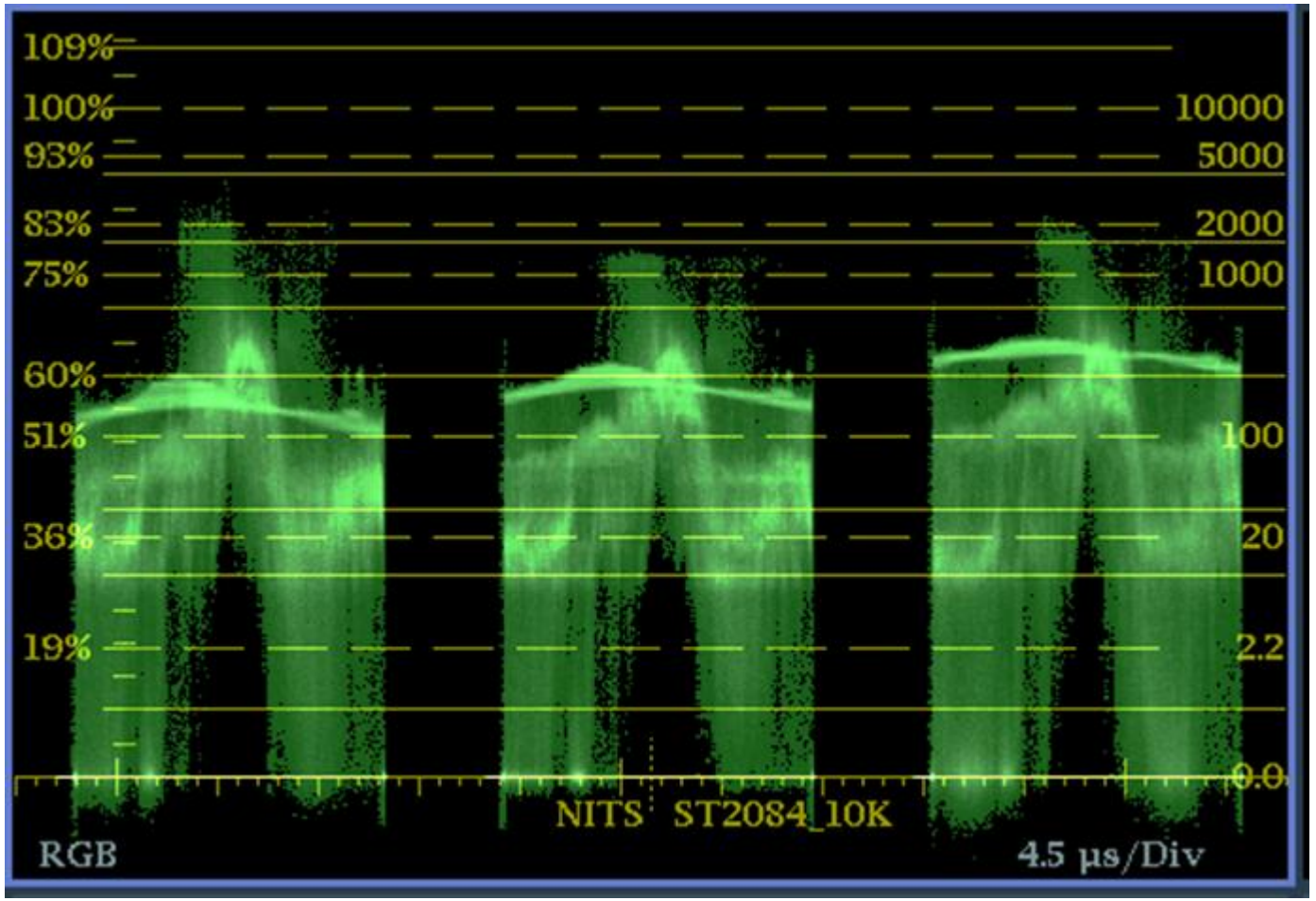
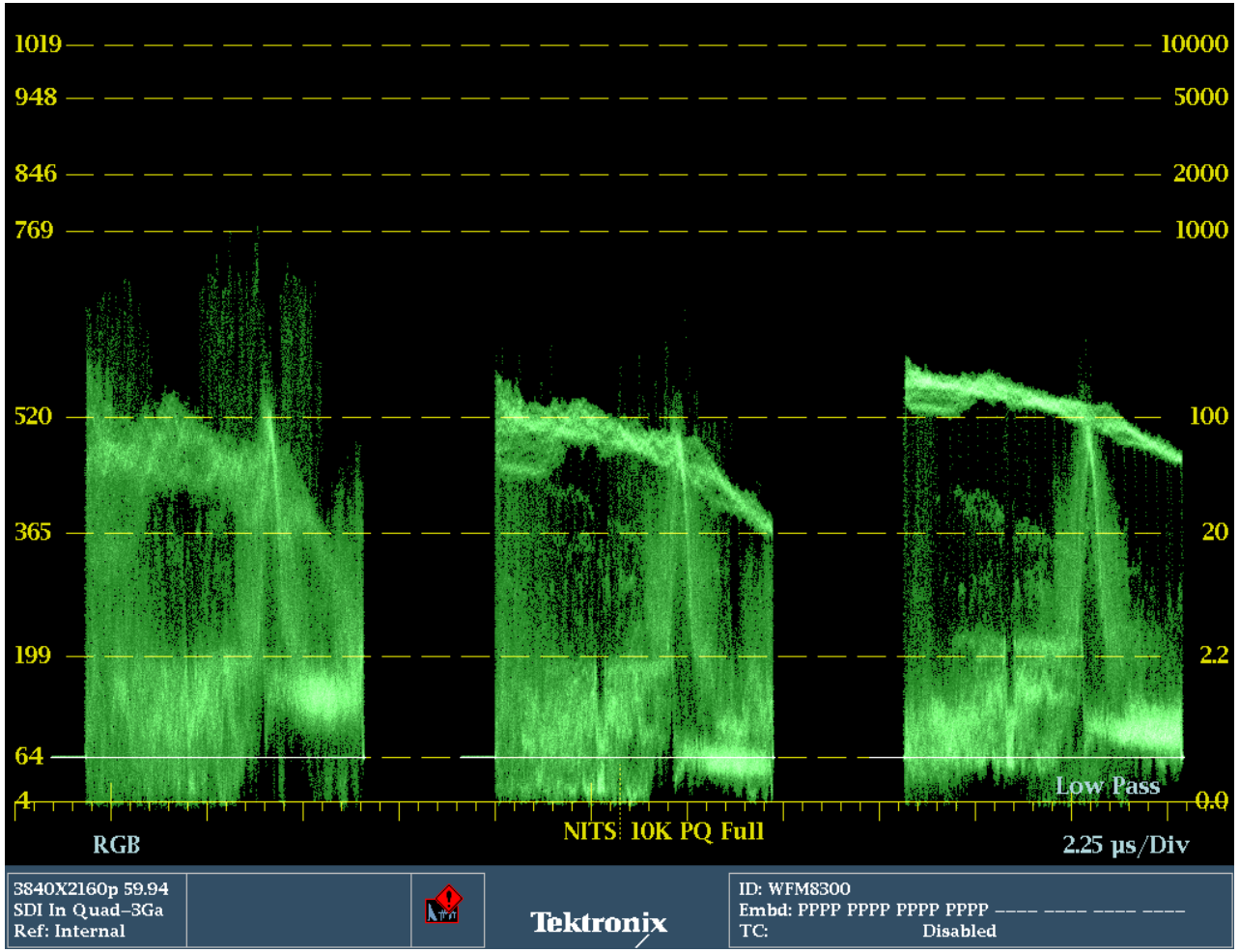
HDR 2K Grade SMPTE Levels.

- Normal Whites are just around 100Nits Maybe just a little higher.
- The Max white is at 2000Nits
- HDR has the blacks stretch and the Whites are compressed



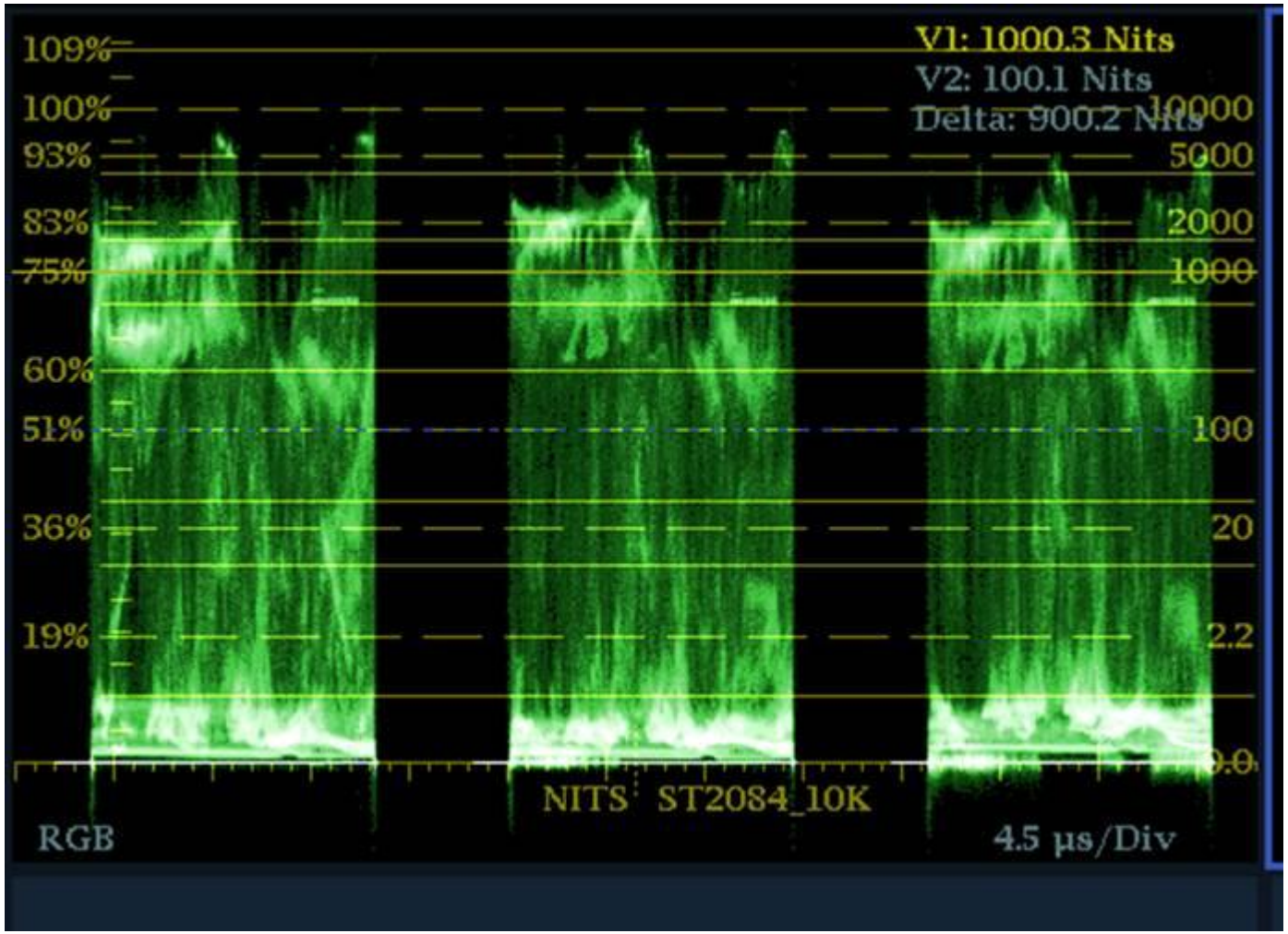
HDR 1K grade full levels

- Black (0) is at 4h
- Normal reflective White is around 100Nits
- Highlights are going up to 1000Nits

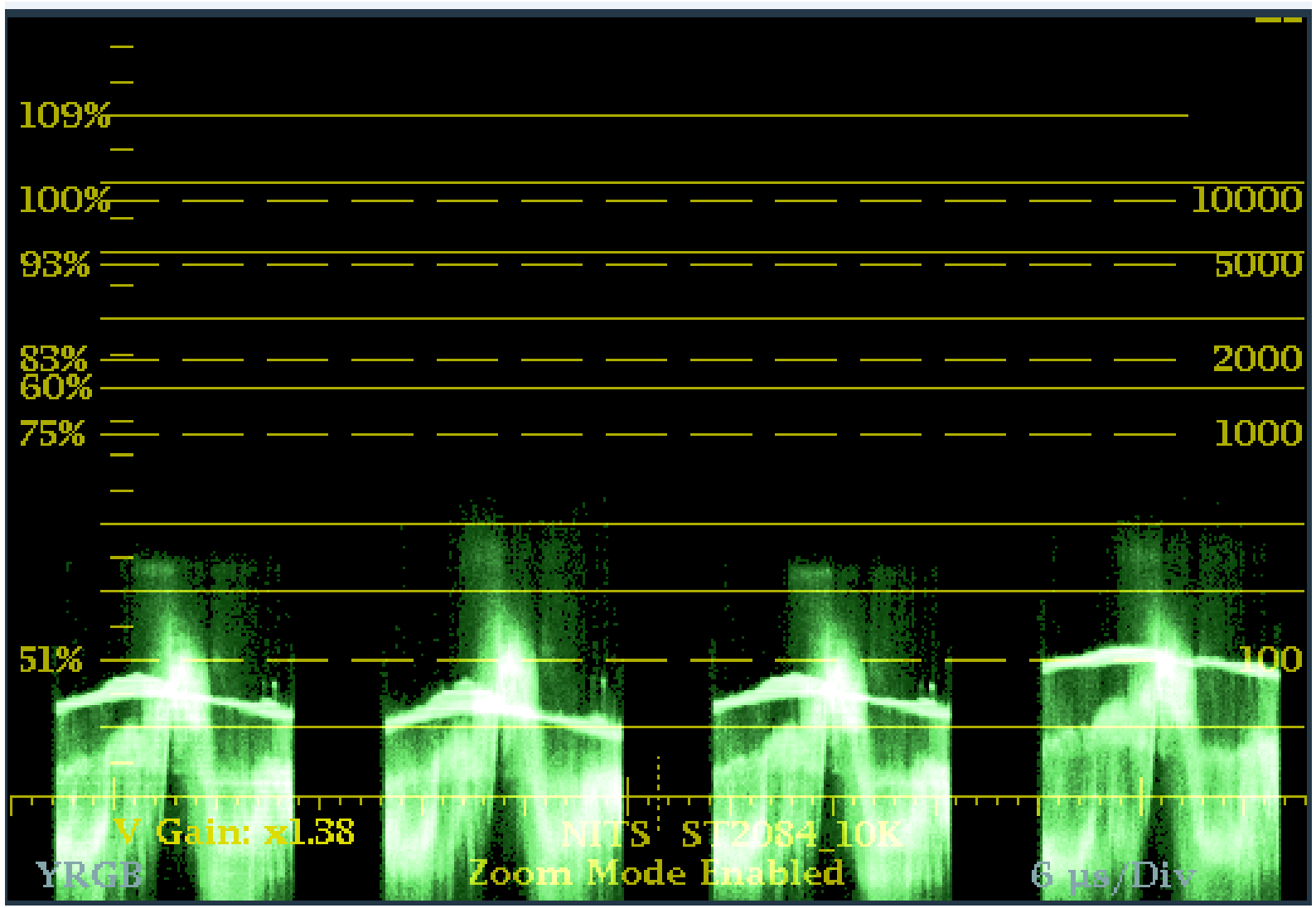


709 Video on the HDR Graticule

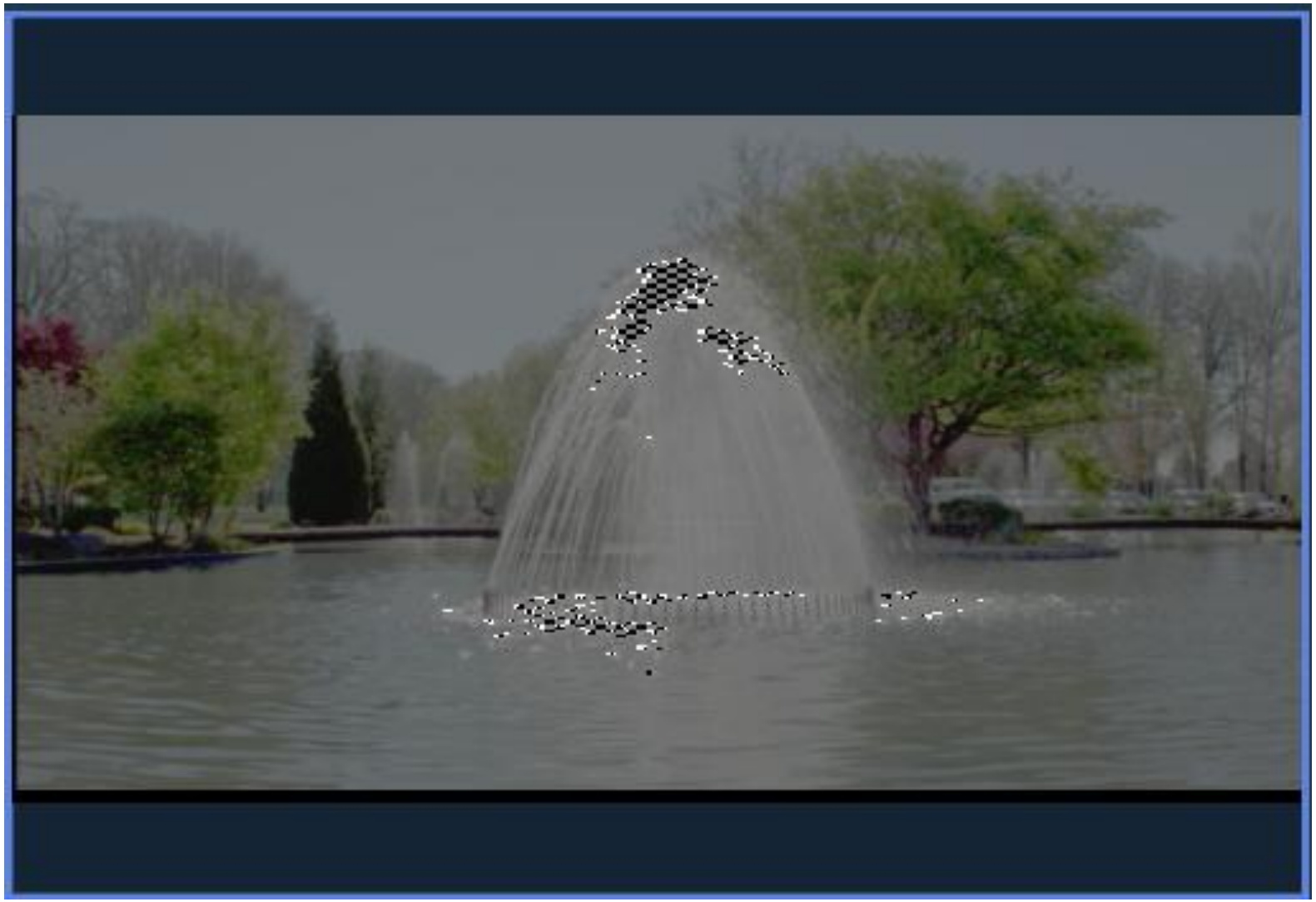
- Notice that the whites are going to 100%
- The black are all down at the bottom of the waveform.
- The whites are stretched to 100%



HDR Zoom Mode



Specular Highlights Bright Ups



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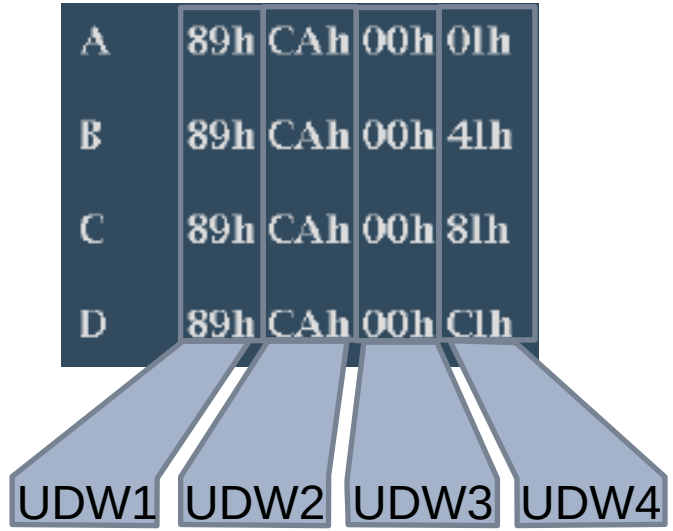
Encoding and Transmission

In SDI we have the Video Payload ID VPID

- The video payload ID tells you a lot about the signal you are receiving
- It is sent as 4 User Data Words (UDW)
- UDW1 – UDW4 you need the magic decoder Ring to decode it correctly

goto www.tek.com/4k to get the PDF with the Decoder Ring.



	Hex	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
UDW 1	XXX	not b8	EP	Version ID	Payload Identifier (See Table D2)						
UDW 2	XXX	not b8	EP	Transport Interface (0) Progressive (1)	Picture Interface (0) Progressive (1)	Reserved 0	Reserved 0	Picture Rate (See Table D3)			
UDW 3	XXX	not b8	EP	Reserved 0[1] Aspect Ratio 4:3 (0), 16:9 (1)	Reserved 0 Horiz. Sampling 1920 (0), 2048 (1)	Reserved 0[2] Aspect Ratio 4:3 (0), 16:9 (1)	Reserved 0[3]	Sampling (See Table D4)			
UDW 4	XXX	not b8	EP	Channel B7 - B6 Single-link or ch1 of multi-channel (0_h), ch2 of multi-channel (1_h), ch3 of multi-channel (2_h), ch4 of multi-channel (3_h), ch5 Reserved (0) Channel B6 Dual link A (0h), B(1h)	Channel B7 - B5 Single-link or ch1 of multi-channel (0_h), ch2 of multi-channel (1_h), ch3 of multi-channel (2_h), ch4 of multi-channel (3_h), ch5 of multi-channel (4_h), ch6 of multi-channel (5_h), ch7 of multi-channel (6_h), ch8 of multi-channel (7_h)		Reserved 0	Reserved 0	Reserved 0 Audio – 3G-SDI Link 2,or 2 to 4, (0) carries additional channels or audio not present (1) carries a copy of 3G-SDI Link 1audio	Bit Depth 8-bit (0_h), 10-bit (1_h), 12-bit (2_h), Reserved (3_h),	
Checksum	XXX	not b8	EP	Sum of B0-B8 of DID to Payload Byte 4							

Poster

4K Ready. Set. Go! 4K/UHD Acquisition to Delivery

Colorimetry

The television color specification is based on standards defined by the CIE (Commission Internationale de L'Éclairage) in 1931. The CIE specified an idealized set of primary XYZ tristimulus values. This set is a group of all-positive values converted from R'G'B' where Y is proportional to the luminance of the additive mix. This specification is used as the basis for color within 4K/UHDTV1 that supports both ITU-R BT.709 and BT2020.

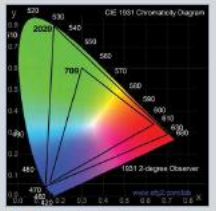


Figure A1: CIE xy diagram with color coordinates used by ITU-R BT.709 and 2020 color spaces.

White Point

The white point of the system within each format is defined by the addition of red, green, and blue in equal quantities. The CIE defined several standard sources in Table A1.

Color Gamut

A color gamut is the complete range of colors allowed for a specific color space. This range is bounded by the xy coordinates of the primary red, green, and blue colors within the color space. The xy coordinates for these primary colors is given for several different gamuts in Table A3.

Table A1: Illuminant (IL) Value

Source	X / Y
Illuminant A: Tungsten Filament Lamp, 2854°K	x = 0.4476 y = 0.4075
Illuminant B: Model of Noon Sunlight, 4800°K	x = 0.3484 y = 0.3516
Illuminant C: Model of Average Daylight, 6504°K	x = 0.3101 y = 0.3162
Illuminant D65: Daylight D Series, 6504°K	x = 0.3127 y = 0.3290
Illuminant (SMPTE/431-2 DCI P3)	x = 0.3140 y = 0.3510

Table A2: Definition of Luma and Color Difference Values

	Rec 601	Rec 709	Rec 2020
Y'	0.299 R' + 0.587 G' + 0.114 B'	0.2126 R' + 0.7152 G' + 0.0722 B'	0.2627 R' + 0.6780 G' + 0.0593 B'
P'b	(B' – Y') / 1.772	(B' – Y') / 1.8556	(B' – Y') / 1.8814
P'r	(R' – Y') / 1.402	(R' – Y') / 1.5748	(R' – Y') / 1.4746

Table A3: CIE XY Coordinates for Various Color Gamuts

Gamut	IL	Red	Green	Blue
ITU-R BT. 2020	D_{65}	x = 0.708 y = 0.292	x = 0.170 y = 0.797	x = 0.131 y = 0.046
ITU-R BT. 709	D_{65}	x = 0.640 y = 0.330	x = 0.300 y = 0.600	x = 0.150 y = 0.060
SMPTE 431-2 (DCI-P3) XYZ		x = 0.680 y = 0.320	x = 0.265 y = 0.690	x = 0.150 y = 0.060
SMPTE	D_{65}	x = 0.630 y = 0.340	x = 0.310 y = 0.595	x = 0.155 y = 0.070
FAL/SSCCAM	D_{65}	x = 0.640 y = 0.330	x = 0.290 y = 0.600	x = 0.150 y = 0.060
NTSC (1953)	C	x = 0.670 y = 0.330	x = 0.210 y = 0.710	x = 0.140 y = 0.080

Figure A2: Using a 100% color bar signal to show conversion of RGB levels from 700 mv (100%) to 0mv (0%) for each color component with a color bar split field BT.2020 and BT.709 test signal. The WFM8300 was configured for BT.709 colorimetry as shown in the video session display.

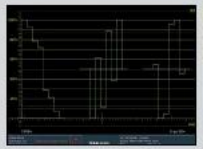


Figure A3: HD YPbPr parade waveform display with 100% color bar test signal, using BT.709 colorimetry.

Figure A4: UHDTV1 YPbPr parade waveform display with 100% color bar test signal, using BT.2020 colorimetry. Notice the difference in the levels between BT.709 and BT.2020 colorimetry shown in Figure A3 and A4.

Image Format / SMPTE Standards

Square Division separates the image into quad links for distribution.

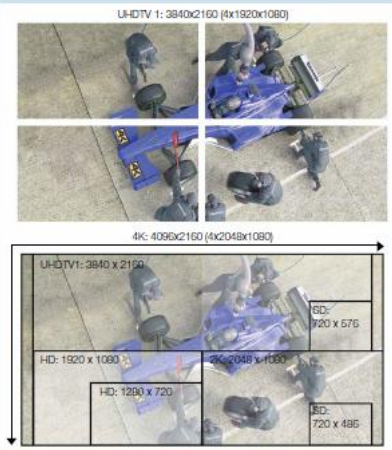


Table B1: SMPTE Standards

SMPTE	Standards
ST 125	SDTV Component Video Signal Coding for 4:4:4 and 4:2:2 for 13.5 MHz and 18 MHz Systems
ST 240	Television – 1125-Line High-Definition Production Systems – Signal Parameters
ST 259	Television – SDTV Digital Signal/Data – Serial Digital Interface
ST 272	Television – Formatting AES/EBU Audio and Auxiliary Data into Digital Video Ancillary Data Space
ST 274	Television – 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates
ST 296	1280 x 720 Progressive Image 4:2:2 and 4:4:4 Sample Structure – Analog & Digital Representation & Analog Interface
ST 299-0/1/2	24-Bit Digital Audio Format for SMPTE 259 Serial Interfaces at 1.5 Gb/s and 3 Gb/s – Document Suite
ST 352	Payload Identification Codes for Serial Digital Interfaces
ST 372	Dual Link 1.5 Gb/s Digital Interface for 1920 x 1080 and 2048 x 1080 Picture Formats
ST 424	3 Gb/s Signal/Data Serial Interface
ST 425-0	Revision of SMPTE 425-0:2012-(M) SMPTE 3G Serial Interfaces at 3 Gb/s – Roadmap for the 425 Document Suite
ST 425-1	Source Image Format and Ancillary Data Mapping for the 3 Gb/s Serial Interface
ST 425-2	Source Image Format & Ancillary Data Mapping for Stereoscopic Image Formats on a Single Link 3 Gb/s Serial Interface
ST 425-3	Image Format and Ancillary Data Mapping for the Dual Link 3 Gb/s Serial Interface
ST 425-4	Dual 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport
ST 425-5	Image Format and Ancillary Data Mapping for the Quad Link 3 Gb/s Serial Interface
ST 425-6	Quad 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport
ST 431-1	D-Cinema Quality – Screen Luminance Level, Chromaticity and Uniformity
ST 435-0	10 Gb/s Serial Signal/Data Interface – Roadmap
ST 435-1	10 Gb/s Serial Signal/Data Interface – Part 1: Basic Stream Definition
ST 435-2	10 Gb/s Serial Signal/Data Interface – Part 2: 10.692 Gb/s Stream – Basic Stream Mapping
ST 435-3	10 Gb/s Serial Signal/Data Interface – Part 3: 10.692 Gb/s Optical Fiber Interface
ST 2036-0	Ultra High Definition Television – Overview for the SMPTE ST 2036 Document Suite
ST 2036-1	Ultra High Definition Television – Image Parameter Values for Program Production
ST 2036-2	Ultra High Definition Television – Audio Characteristics & Audio Channel Mapping for Program Production
ST 2036-3	Ultra High Definition Television – Mapping into Single-link or Multi-link 10 Gb/s Serial Signal/Data Interface
SMPTE 2081-0	SMPTE 6G Serial Interfaces at 6 Gb/s – Overview for the SMPTE ST 2081 Document Suite
SMPTE ST 2081-1	6 Gb/s Signal/Data Serial Interface – Electrical
SMPTE ST 2081-10	2160-Line and 1080-Line Source Image and Ancillary Data Mapping for Single-Link 6G-SDI
SMPTE 2082-0	12G-SDI Bit-Serial Interfaces – Overview for the SMPTE ST 2082 Document Suite
SMPTE ST 2082-1	12 Gb/s Signal/Data Serial Interface – Electrical
SMPTE ST 2082-10	2160-Line Source Image and Ancillary Data Mapping for 12G-SDI

Transport / Timing

4K/UHDTV1 Quad Link requires that the image be segmented into two or four links depending on the frame rate of the video. In Quad Link there are two processes for segmenting the picture using either square division or two-sample interleave.

Square Division (Tile Mode)

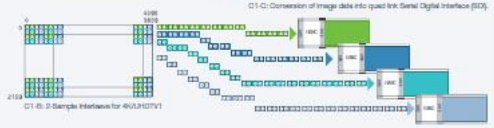
In this process the image is divided into four quadrants and then sent on four separate SDI cables, see Figure C1-A. This process is the simplest method for segmenting the image but requires more memory to store each of the quadrants before assembling the complete image and is commonly used by a variety of post-production equipment.

C1-A: Square Division for 4K/UHDTV1

C1-C: Conversion of image data into quad link Serial Digital Interface (SDI).

2-Sample Interleave

In this process groups of two pixels are separated from the image and sent on four different links as shown in Figure C1-B. This method requires less memory to be used and allows groups of pixels to be processed more quickly. However this process requires multiplexing of the data into four separate SDI streams. 2-Sample Interleaving has applications within the transmission process.



C1-B: 2-Sample Interleave for 4K/UHDTV1

Timing

Within Quad link SDI distribution for 4K/UHDTV1 each link will be routed differently within the network. Therefore care should be taken to ensure that each link is received at the device within certain tolerances. SMPTE standards define the timing difference between EAV (End of Active Video) / SAV (Start of Active Video) (see Figure C1-C) of Link A to Link D shall not exceed 400ns at the source. No specification is given for the receiving device and will depend up on the equipment as to how much timing difference the unit can tolerate.

The Tektronix 8000 Series Waveform Monitor and Rasterizers allow for 1024 clocks of timing difference between the inputs and will provide measurement of the timing difference between the Inputs (Figure C2).

Figure C2: Input timing to external reference shown on the Tektronix WFM/WFM8300 Series Waveform Monitor.

Table C1: Frame Rate Timing

Ensuring the correct frame delay is critical within these video systems and Table C1 shows the duration in milliseconds for each progressive frame rates.

Frame Rate (Hz)	23.98	24.00	25.00	29.97	30.00	47.95	48.00	50.00	59.94	60.00
Duration (ms)	41.71	41.67	40.00	33.37	33.33	20.86	20.83	20.00	16.68	16.67

Video Payload Identifier

The SMPTE ST 352 Video Payload Identifier (VPID) is carried within the Ancillary data space to assist a device in quickly decoding the video signal.

The 8000 Series Waveform Monitors and Rasterizers can show the VPID within the video session display and the data values can be found in the Ancillary Data Display or Datalist displays.

The VPID conforms to the SMPTE 291 Ancillary Data Packet and Space Formatting standard and contains the Ancillary Data Flag (ADF), Data Identifier (DID), Secondary Data Identifier (SDID), Data Count, User Data Words (UDW 1-4) and Checksum as shown in Table D1.

Note: There is no specific value to determine 2-Sample Interleave or Square Division. Therefore if the VPID is consistent with ST 425-3 or ST 425-5 we assume sample interleave. If the VPID is standard (-M) ST 292 or ST 425-1 (2K) the format is consider Square Division. The user can also manually configure this within the instrument.

Figure D1. WFM8000 quad link Datalist display show the VPID ANC data for each link.

Table D1. Video Payload Identifier Ancillary Data Packet

Note: Please refer to latest standard for complete details of VPID information.

	Hex	B9	B8	B7	B6	B5	B4	B3	B2	B1	B0
ADF	000	0	0	0	0	0	0	0	0	0	0
	3FF	1	1	1	1	1	1	1	1	1	1
	3FF	1	1	1	1	1	1	1	1	1	1
DID	241	not b8	EP	0	1	0	0	0	0	0	1
SDID	101	not b8	EP	0	0	0	0	0	0	0	1
DC	104	not b8	EP	0	0	0	0	0	1	0	0
UDW 1	XXX	not b8	EP	Version ID				Payload Identifier (See Note 2)			
UDW 2	XXX	not b8	EP	Transport Identifier (See Note 3)		Picture Identifier (See Note 3)		Reserved 0	Reserved 0	Picture Rate (See Note 4)	
UDW 3	XXX	not b8	EP	Reserved (See Note 5)		Reserved (See Note 5)		Reserved (See Note 5)	Sampling (See Note 6)		
UDW 4	XXX	not b8	EP	Channel B7 - B6		Channel B7 - B6		Reserved 0	Reserved 0	Reserved 0 (See Note 7)	Bit Depth (See Note 8)
Checksum	XXX	not b8	EP	Sum of B0-B8 of DC to Payload Byte 4							

Table D2: SMPTE 352 Video Payload Identifier UDW 1

Byte 1 Bit 7-0		Std. Reference
Decimal	Hex	
129	81h	SMPTE ST 259 (SD)
132	84h	SMPTE ST 292-1 (720p)
133	85h	SMPTE ST 292-1 (1080i)
135	87h	SMPTE ST 372 (Dual Link)
137	89h	SMPTE ST 425-1 (3G Lvl A)
138	8Ah	SMPTE ST 425-1 (3G Lvl B)
140	8Ch	SMPTE ST 425-1 (0x1080i 3G B)
144	90h	SMPTE ST 435-1 (10 Gb)
148	94h	SMPTE ST 425-3 (Dual 3G A)
149	95h	SMPTE ST 425-3 (Dual 3G B DL)
150	96h	SMPTE ST 425-3 (Dual 3G B SL)
151	97h	SMPTE ST 425-5 (Quad 3G A)
152	98h	SMPTE ST 425-5 (Quad 3G B)
160	A0h	SMPTE ST 435-1 (Octa 10G)
161	A1h	SMPTE ST 2036-3 (4K 10G)
162	A2h	SMPTE ST 2036-3 (8K 10G)
165	A5h	SMPTE ST 2036-4 (4K 10G)
166	A6h	SMPTE ST 2036-4 (8K 10G)
170	B2h	SMPTE ST 2048-3 (4K 10G)
192	C0h	SMPTE ST 2081-10 Mode 1
193	C1h	SMPTE ST 2081-10 Mode 2
194	C2h	SMPTE ST 2081-11 Mode 1
195	C4h	SMPTE ST 2081-12 Mode 1
206	C5h	SMPTE ST 2082-10 Mode 1
207	C7h	SMPTE ST 2082-10 Mode 2

Table D3. Picture Rate

Value	Picture Rate
0h	No defined value
1h	Reserved
2h	24/1.001
3h	24
4h	48/1.001
5h	25
6h	30/1.001
7h	30
8h	48
9h	50
Ah	60/1.001
Bh	60
Ch	Reserved
Dh	Reserved
Eh	Reserved
Fh	Reserved

Table D4. Sampling Structure

Value	Sampling
0h	4:2:2 (YCbCr)
1h	4:4:4 (YCbCr)
2h	4:4:4 (G/B/R)
3h	4:2:0
4h	4:2:2:4 (YCbCrA)
5h	4:4:4:4 (YCbCrA)
6h	4:4:4:4 (G/B/RA)
7h	SMPTE ST 2048-2 F-5
8h	4:2:2:4 (YCbCrD)
9h	4:4:4:4 (YCbCrD)
Ah	4:4:4:4 (G/B/RD)
Bh	Reserved
Ch	Reserved
Dh	Reserved
Eh	Reserved
Fh	Reserved

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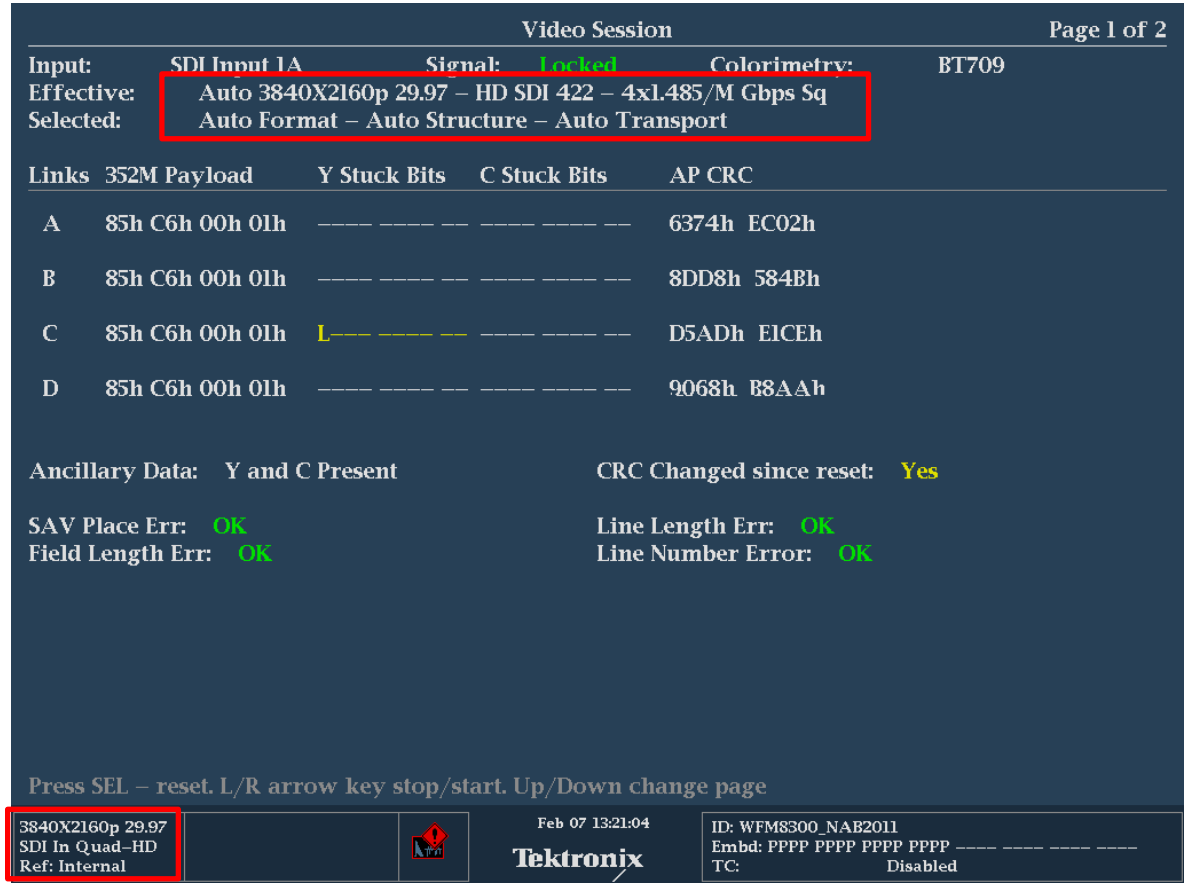
Different VPID's The Waveform Monitor provides the Magic Decoder



This one is different VPID for each Link
And is UHD 59.94p Y Cb Cr
Quad 3G level A

This one is the same VPID for each Link
And is UHD 29.97p Y Cb Cr
Quad HD

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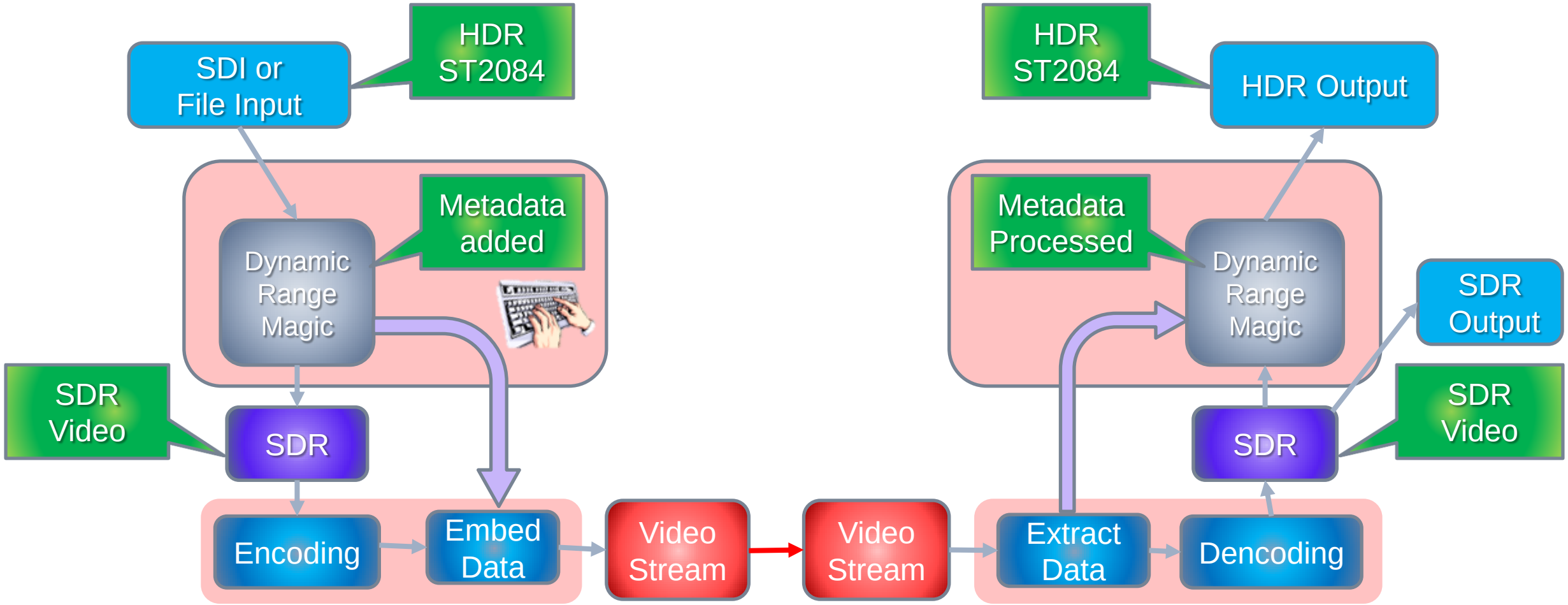
SDI Metadata

- At this point in time there is no Metadata other than VPID that is being carried in the SDI feed.
- So that means that the SDI transport is linear in respect to the content being Rec709, Rec 2020, or DCI P3 Color and if it is for UHD Alliance, Static Meta Data, Dynamic Metadata they will all look the same, all use the ST 2084 curve.
- You need to know;
  - Is it a ST2084 PQ curve or HLG
  - What is the diffuse white point
  - What is the Grade point 1K Nits, 2K Nits, 540 Nits or?
  - Is it Full levels or Narrow levels (SMPTE Levels)

- The Metadata for HDMI and the Monitor will be added when the Content is Encoded. Either manually typed in or read from a Metadata sidecar file.

Encoding and Transmission HDR

SDR SENT AS BASE LAYER METADATA SENT FOR HDR



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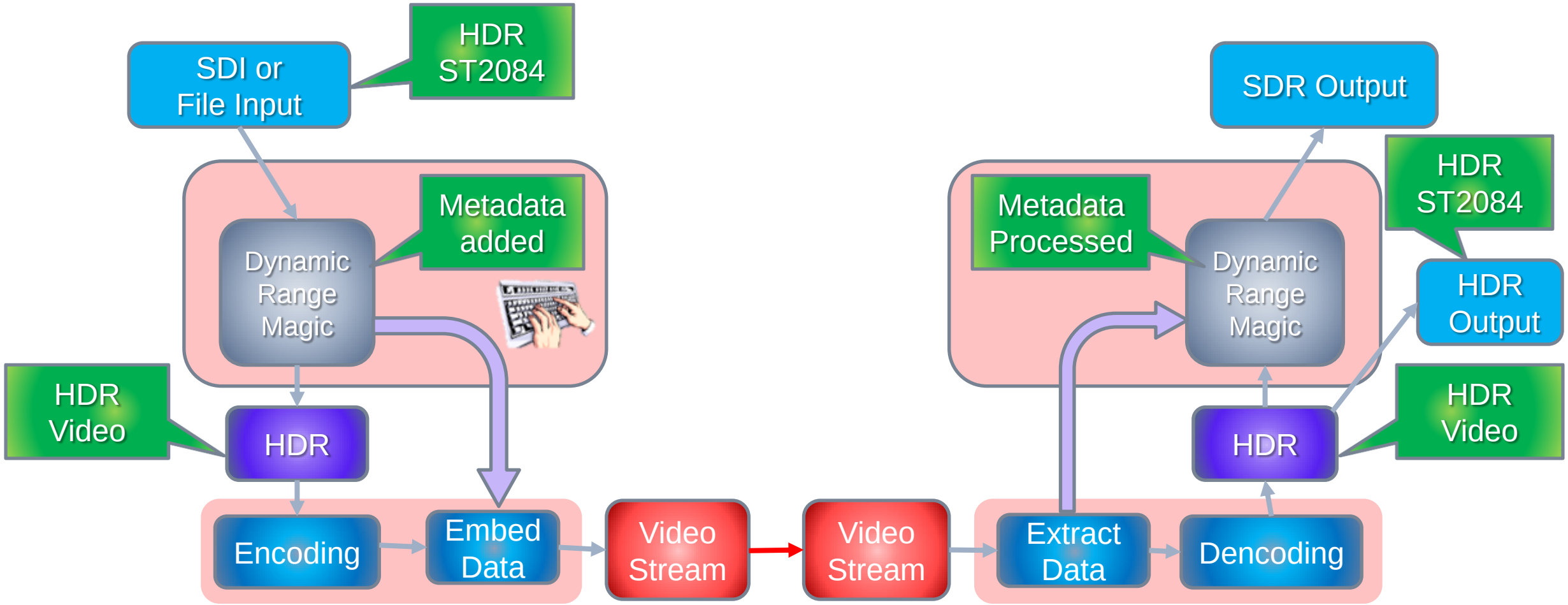
Encoding and Transmission HDR

HDR SENT AS BASE LAYER METADATA SENT FOR SDR



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HEVC HDR Metadata

METADATA IS CARRIED IN THE SEI MESSAGE

Video standard	HEVC Main 10 Profile/ Main Tier/ Level 5
HDR Info	UUID:-427fcc9bb89248219561c292e3a1fdf3 Mastering display color primaries: R:x=(0.708)y=(0.292) G:x=(0.17)y=(0.797) B:x=(0.131)y=(0.046) White point:x=(0.3127)y=(0.329) Mastering display luminance: Min:0cd/m2, Max:1000cd/m2 Maximum Content Light Level(MaxCLL):800cd/m2 Maximum Frame-Average Light Level(MaxFALL):400cd/m2 Color primaries:Rec. ITU-R BT.2020 Transfer Characteristics:SMPTE ST 2084 Matrix Coefficients:ITU-R BT.2020 non-constant luminance system

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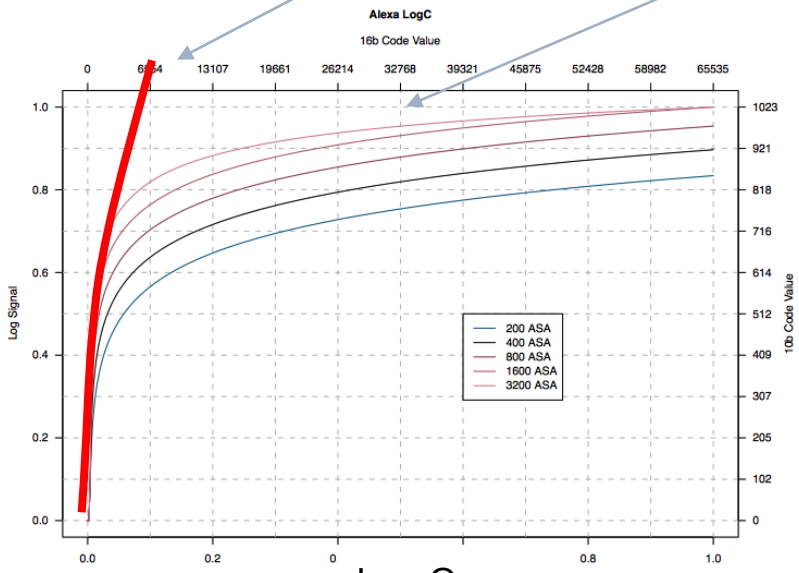
Camera Log　(Log Scale on Waveform Monitor)

Log

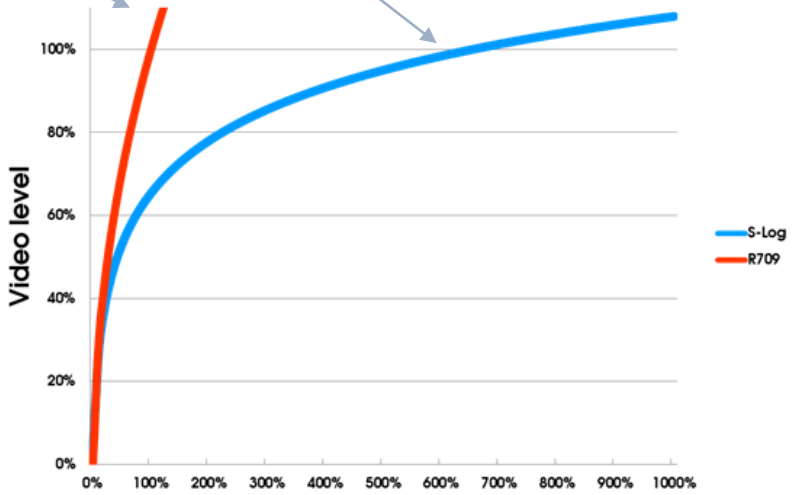
- What is Log gamma? It's an option on most modern digital cinema cameras that allows you to shoot as flat an image (color and luminescence wise) as possible.
- Look at these charts below that show the difference between two cameras' default color options and their log options:

709

Log



Log-C



S-Log

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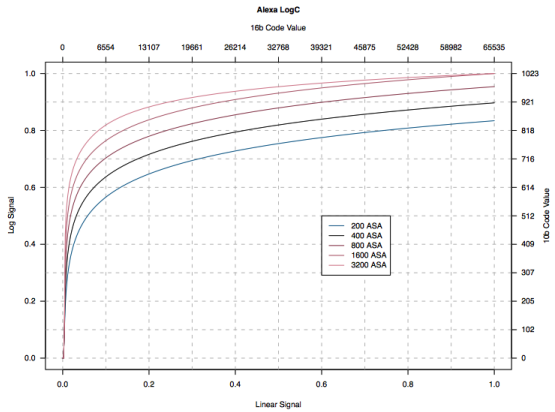
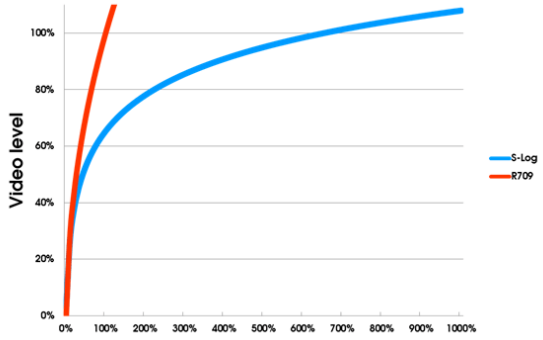
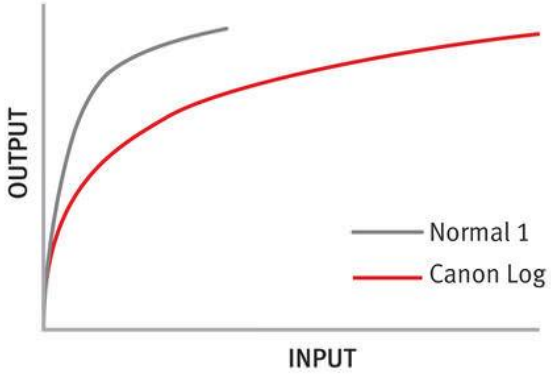
Log (cont)

- In these charts the further to the right the line is the longer it takes to reach the top, the more information is being recorded. This extra information gives you much more latitude in post-production to manipulate the colors, shadows, and highlights.
- Sometimes shooting log gamma is also referred to as “shooting flat” Shooting a flat image gives you more details in both highlights and dark areas. While a flat image may not look pleasing while on set, it provides more freedom for color grading in post-production. It allows you to show what’s outside the window as well as what’s inside the room.







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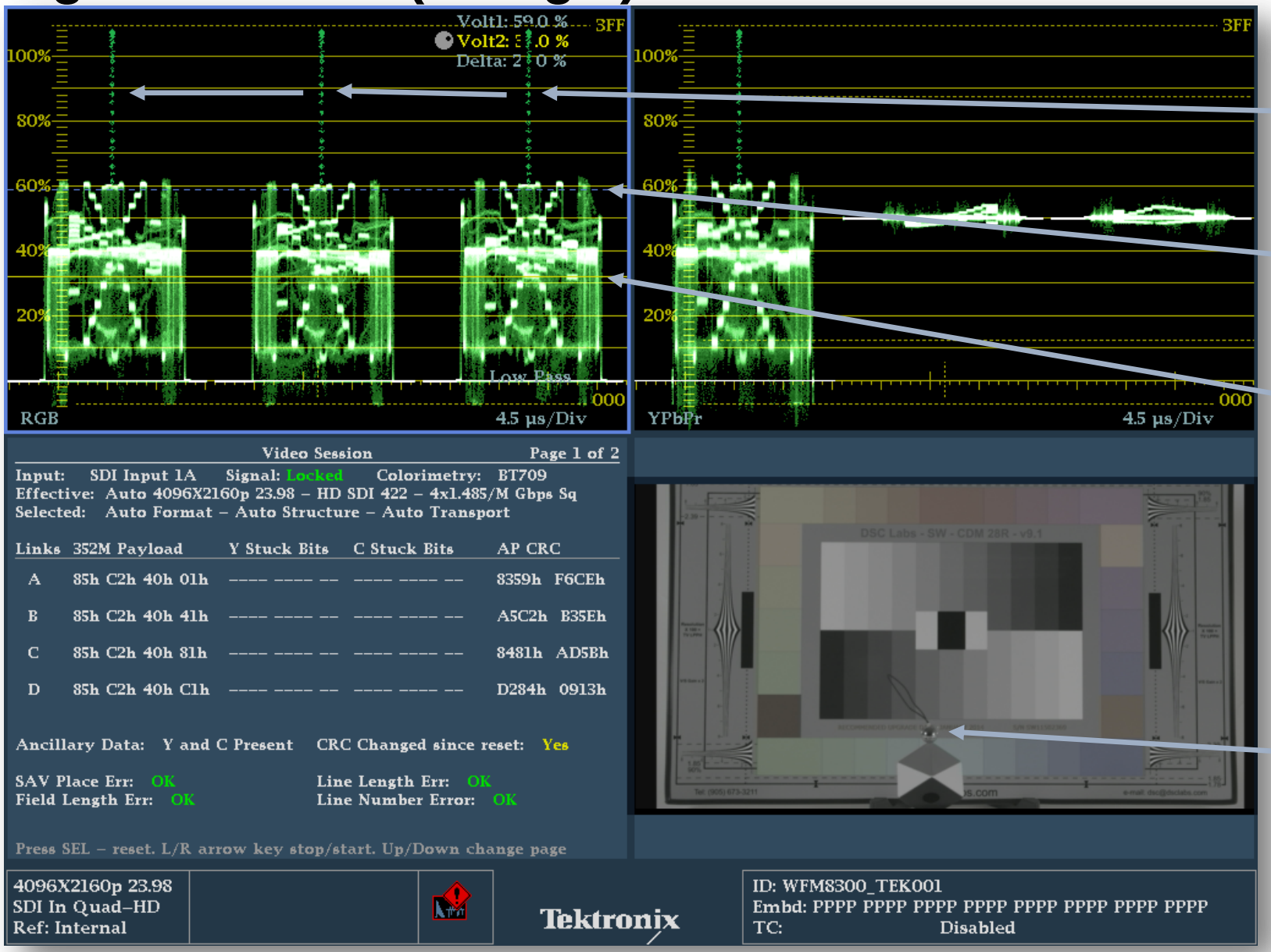
Log Log Waveform (S Log 2)



Specular highlight is going to the top

Normal White is at 59%

18% black is at 32%

We have placed cursers at 59% and 32%

Highlight is from the silver ball

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Capturing a Camera Log image

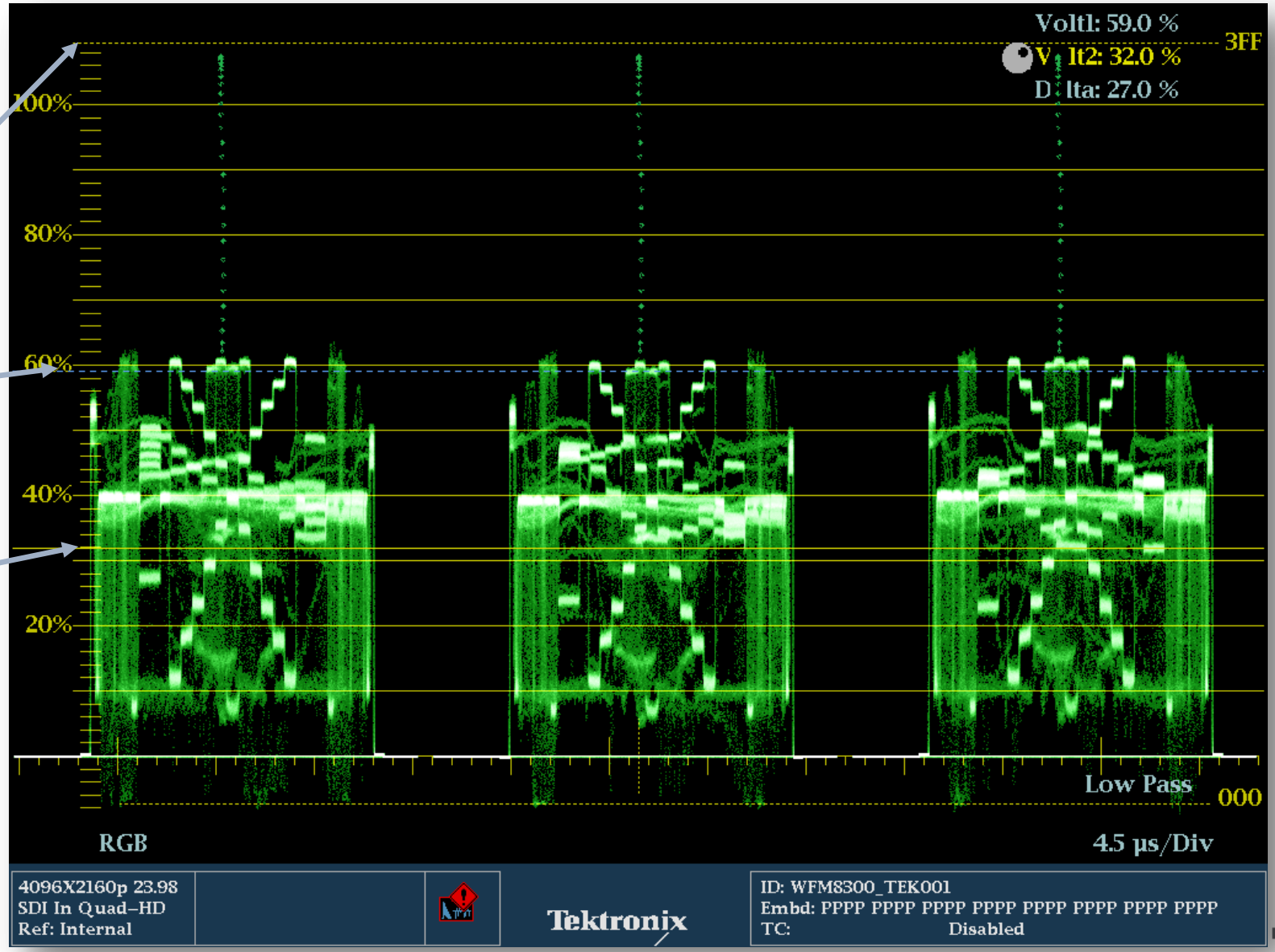
Gamma	0% Black 10-bit Code-Value	%	18% Grey (20 nits illumination) 10-bit Code-Value	%	90% Reflectance 10-bit Code-Value	%
S Log 1	90	3	394	37.7	636	65
S Log 2	**90**	**3**	**347**	**32.3**	**582**	**59**
S Log 3	95	3.5	420	40.6	598	61
LogC	134	3.5	400	38.4	569	58
C-Log	128	7.3	351	32.8	614	63
ACES (proxy)	ND	ND	426	41.3	524	55
BT.709	64	0	423	41.0	940	100

S Log 2 Waveform to Nits

540 or 1000 Nits
Max Highlights
Monitor dependent

100 Nits
Normal White

20 Nits
18% Grey



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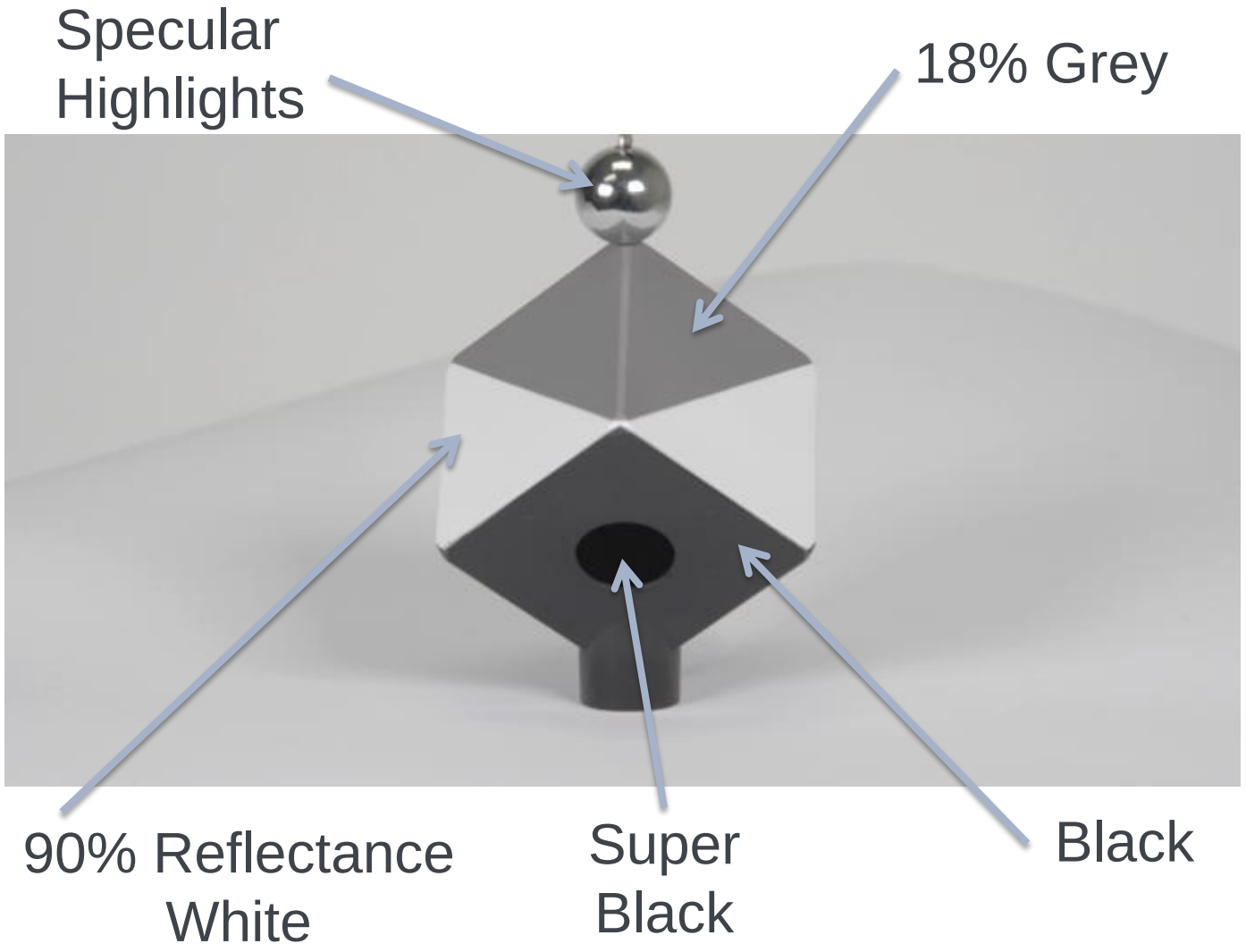
Capturing Camera Log Footage (Spider cube)

- Setup your test chart within the scene
- Adjust the lighting to evenly illuminate the chart
- Adjust the camera controls to set the levels
  - ISO/Gain, Iris, Shutter, White Balance



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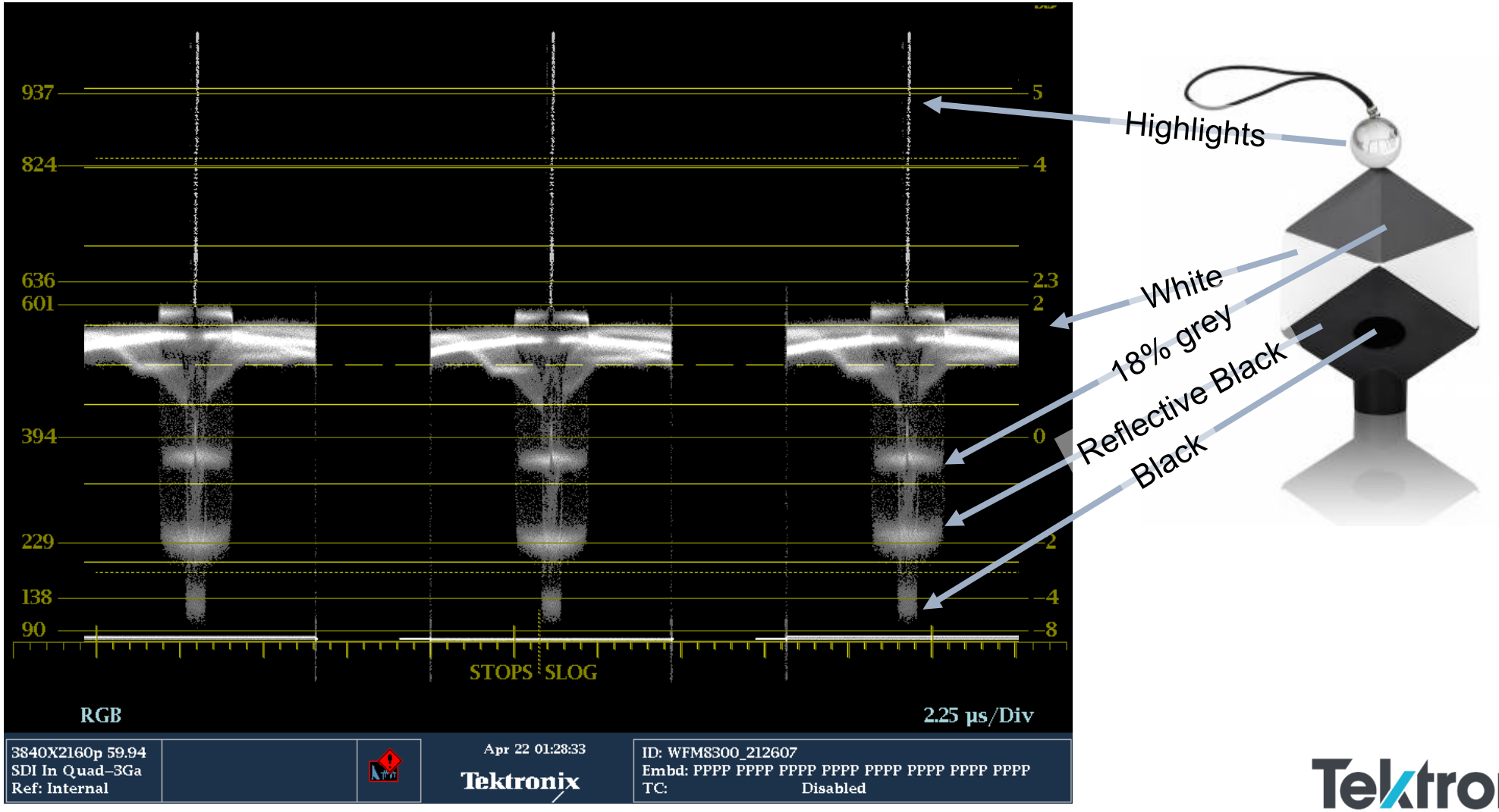
Spider Cube S Log 2 as shot from the Camera in Log

Showing Graticules in Digital Values and Stops

Digital Values on the Left side

Stop values on the right side.



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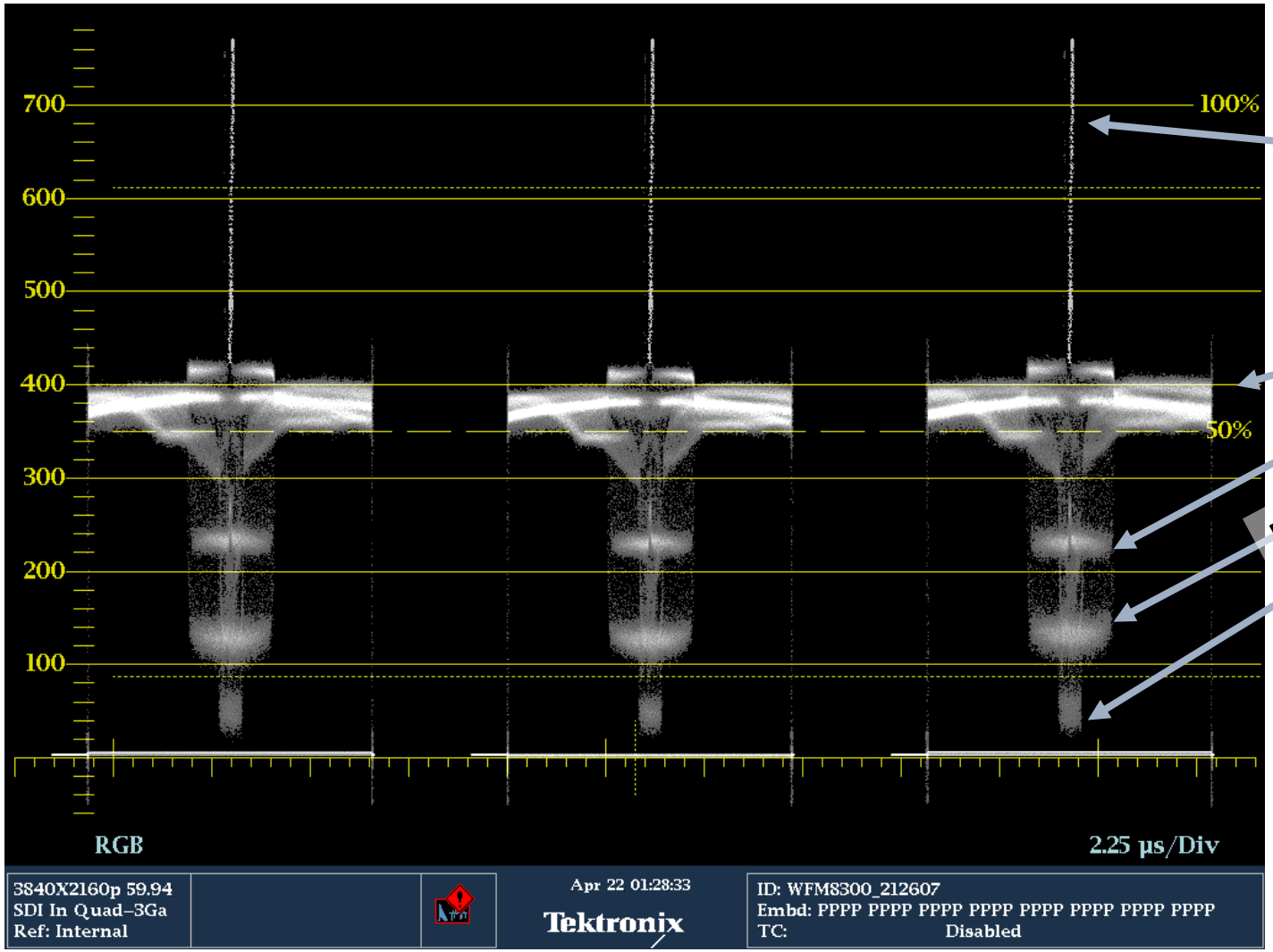
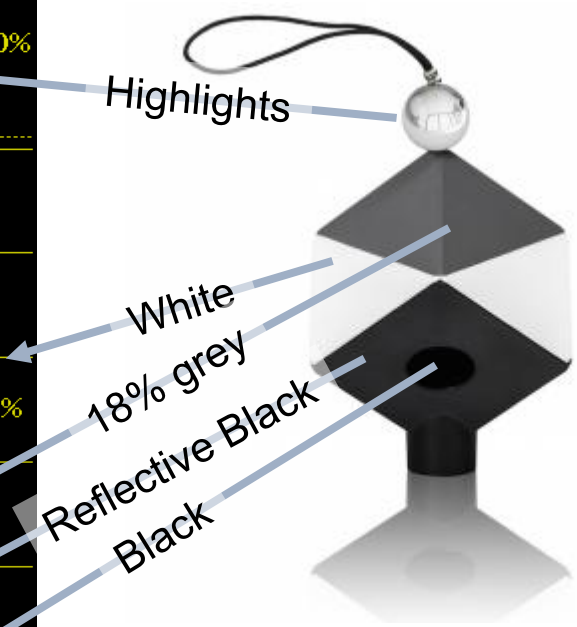
Spider Cube S Log 2 as shot from the Camera in Log

Showing S Log 2 in normal 709 type screens





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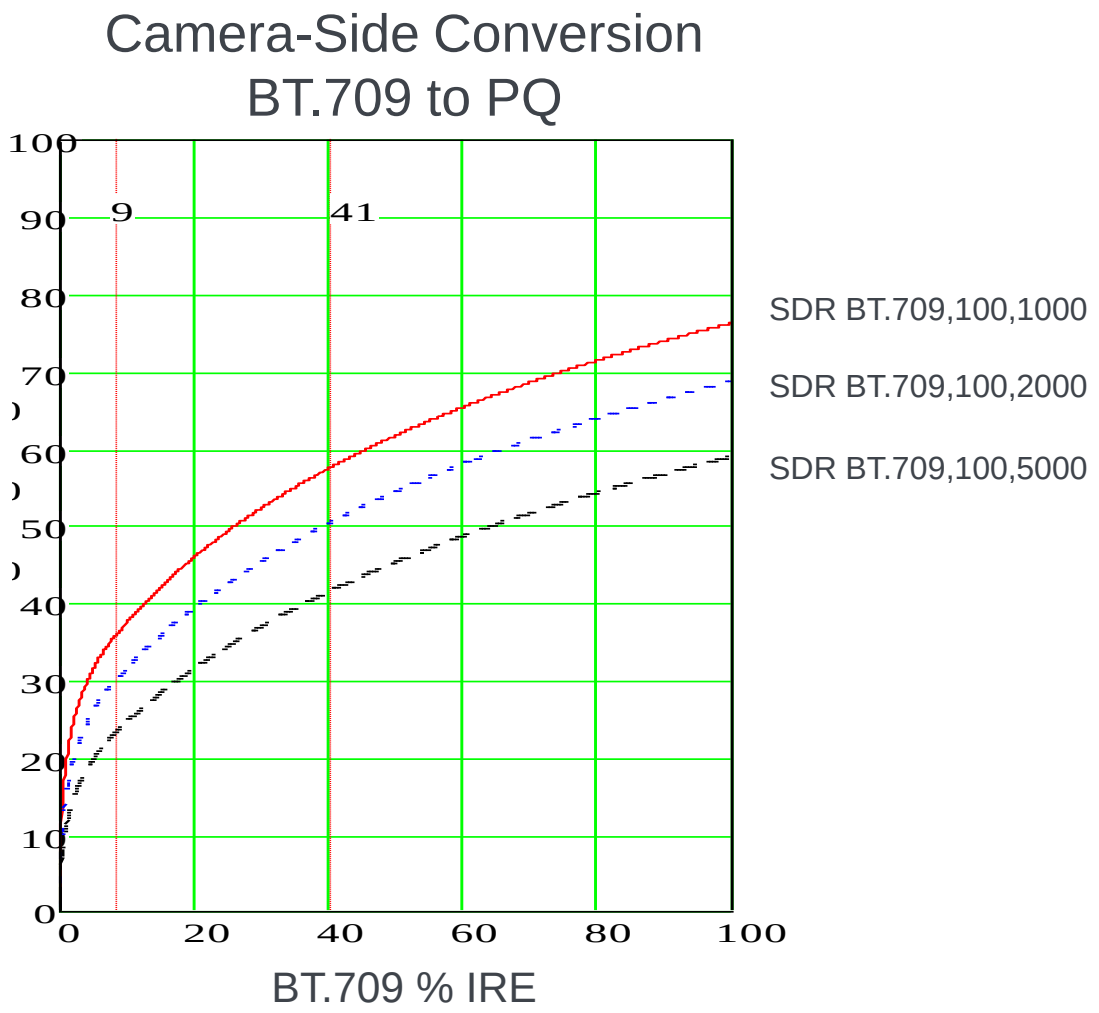
Camera (scene) referenced 709 to PQ LUT conversion

2084 HDR	0%	2%	18 %	90%	100%
709 100nits	0	9	41	95	100
HDR 1000nits	0	37	58	75	76
HDR 2000nits	0	31	51	68	68
HDR 5000nits	0	24	42	58	59



SDR and HDR displays DO NOT match.
Blacks are stretched in the BT1886 Display but not the PQ Display (matches scene)

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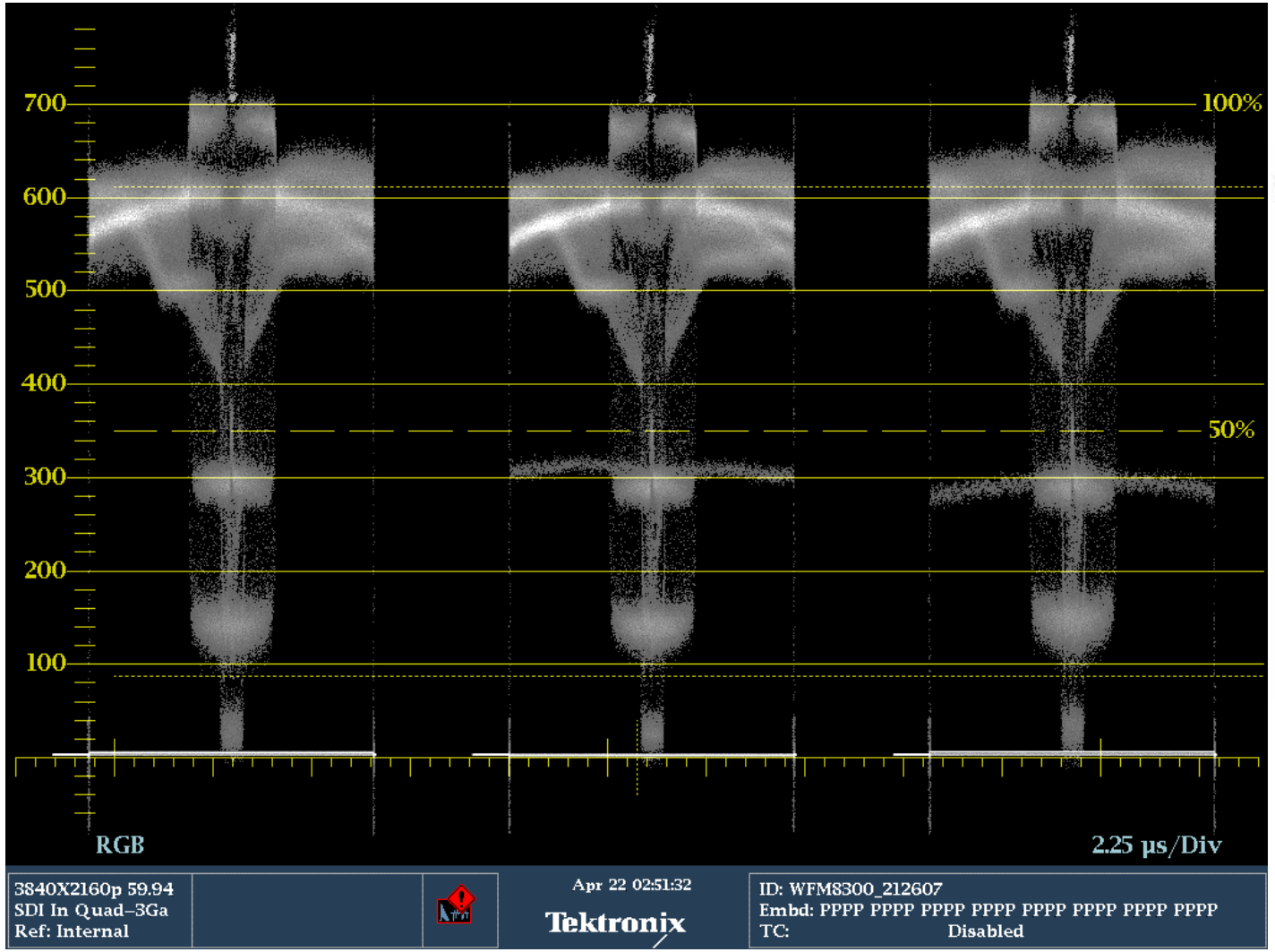
S Log 2 to Rec. 709



HDR With twin pickups

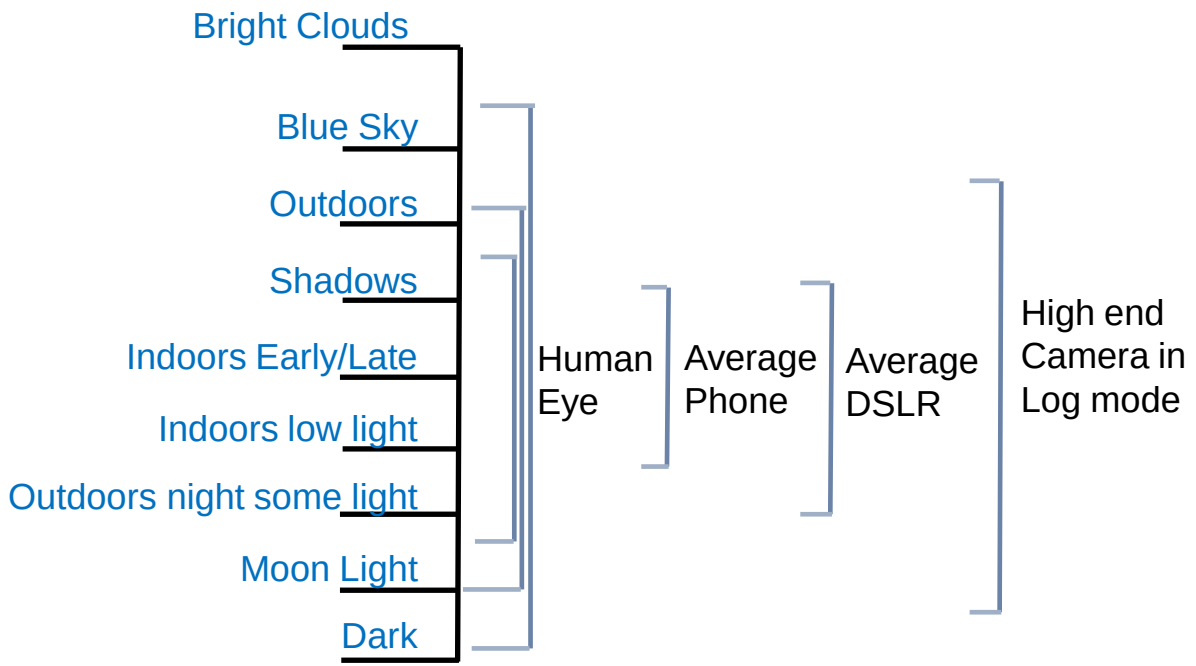
- One method was duplicating what is done in photography is using two cameras with a beam splitter, but unlike 3D where you have an offset the image was the same in both cameras. But they were set up differently. One was underexposed while the other was overexposed and both were pointed at the same subject matter. Now that would generally cause a visual offset, hence the beam splitter which allowed both lenses to see the exact same image.

Contrast Ratios

The human eye can adapt to different lighting conditions quickly Sliding up and down the scale

The adapted human eye can see about 7 stops but, with local adaption, can see 10-14 stops of dynamic range in a single, large area image. With longer term adaption the human eye can see about 24 stops! Therefore, higher dynamic range results in an experience closer to reality. Also, higher dynamic range increases the subjective sharpness of images and perceived color saturation.

SDR video with a 2.4 gamma curve and a bit depth of 8-bits per sample has a dynamic range of about 6 stops. Professional SDR video with a bit depth of 10-bits per sample has a dynamic range of about 10 stops. When HDR is displayed on a 2,000 Nit display with a bit depth of 10-bits per sample it has a dynamic range of about 200,000:1 or over 17 stops



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Total Visual Dynamic Range

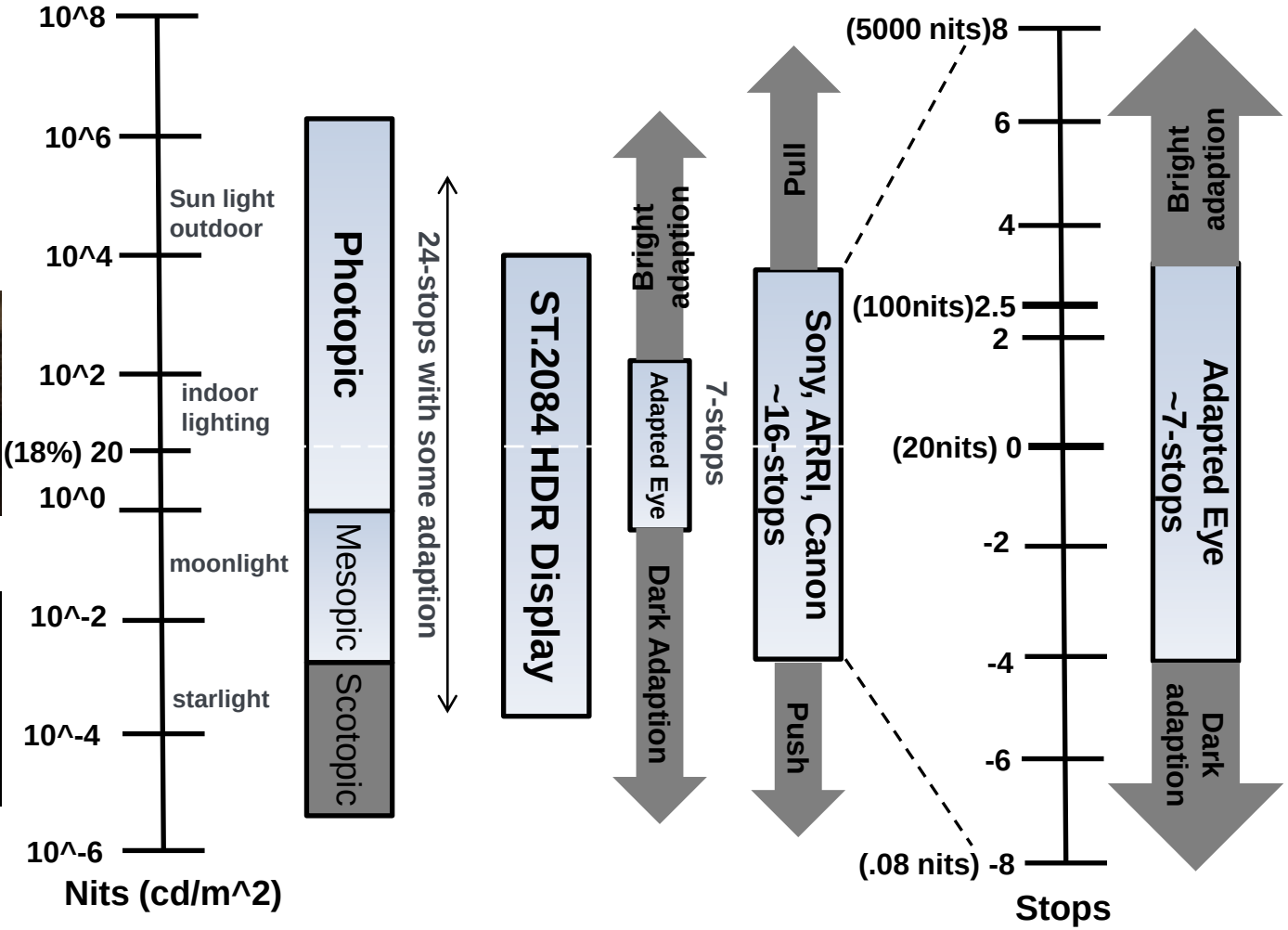
HDR MAPPING INTO CAMERA F-STOPS (0 = 18% REFLECTANCE)

Sunlight outdoor

Indoor Lighting

Moonlight

Starlight



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- ***Hybrid Log Gamma BBC white paper***; http://downloads.bbc.co.uk/rd/pubs/whp/whp-pdf-files/WHP283.pdf
- **Various examples of 4K where HDR makes it better;** http://4k.com/video/
- ***Stop Weighted Waveform***; **US Patent Application 20150348281, published Dec. 3, 2015, Baker, Daniel G., Tektronix, Inc.**

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THANK YOU

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