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Video Standards

Signals, Formats and Interfaces

Part 10

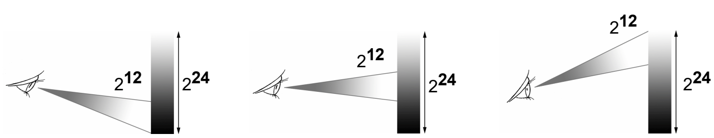
HDR Video Flavors & Inconvenient Truth

www.videoq.com

Dynamic Range – Capture, Display, Enjoy

Captured light levels **ratios** are traditionally specified in 'lens stops', 'one stop' means doubling, or halving, of the amount of light reaching the sensor. **Human eye dynamic range** is very large: ≈ 24 stops, ratio of the lightest visible gradation to the darkest visible gradation ≈ 2^{24} ≈ 16,000,000 times. However, this is the 'total dynamic range' of a human eye distinguishing two **adjacent** brightness gradations in the **long adaptation time conditions**. So called '**static dynamic range**' (range of discernible light gradations **viewed simultaneously**) is much smaller – less than 12 stops, ≈ 4,000.

Science can be funny.
E.g. combining in one term two mutually exclusive *words: 'static'* and *'dynamic'*.

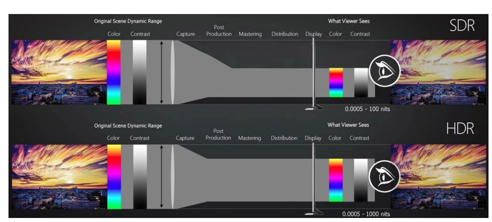


Important conclusion:

Humans can not see details of a sunny beach and dark cellar **simultaneously**

This well known marketing diagram is incorrect:

1. In real living room conditions SDR & HDR **bottom** limits are the **same**
2. SDR camera doesn't pick up the **middle** sub-range, but **any** sub-range



The "amended" diagram is **closer to reality**, *but it is also debatable*:

1. SDR White on a modern HDR screen is **not 100 nt**, but **much higher**
2. HDR White is **below** the SDR White; only **specular highlights** are higher

Images – courtesy of "Light Illusion", https://www.lightillusion.com/uhdtv.html

Bright Colors & Perceived Light Levels

The **subjective perception** of color video images light levels may differ significantly from the **photometric brightness** in cd/m^2 defined in CIE 1931 standard.

CIE 1931 formula for the **photometric brightness**: **Y = 0.222*R + 0.707*G + 0.071*B**.
In this formula R, G and B are not video signals, but relative light levels in percents (R, G and B channels EOTF outputs), and Y is the resulting brightness in percents. Traditionally the **relative** brightness is expressed as a percentage — always with reference to **White**.

Typical answer to the question 'Which color bar in this test pattern is brighter?' is: ''All bars, except black, are **equally** bright".

Thus, the commonly used *de-facto* formula (*not yet mentioned in standards*) of perceived **L**ight **L**evel is: LL = max(R,G,B), in nits or percents.

COLOR	CIE 1931 RELATIVE *BRIGHTNESS*, %	PERCEIVED RELATIVE *LIGHT LEVEL*, %
WHITE	100	100
YELLOW	92.9	100
CYAN	77.8	100
GREEN	70.7	100
MAGENTA	29.3	100
RED	22.2	100
BLUE	7.1	100
BLACK	0	0

BTW:
*Rendering of full frame 100% solid **Blue** on the bright **backlit HDR LCD screen** requires maximum light source power, e.g. **500 W**.*

*But this **White** light power must be **blocked** in **G** and **R** channels by the tiny LCD light-valve cells.*

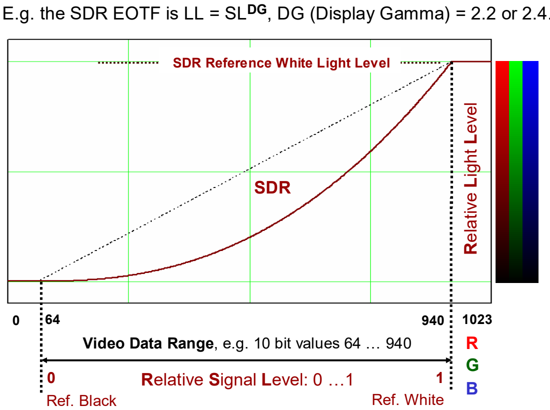
*It means massive heat dissipation (500 x 2/3 = **333 W**) within the relatively **thin** object – i.e. danger of the LCD screen over-heating.*

From Signal to Light

Currently there are 4 types of video data formats in use, based on different Signal ⇔ Light mapping schemes aka Dynamic Range (**DR**) Models:

- Ubiquitous widespread **SDR** (Standard Dynamic Range) format
- **HDR-LOG** (High Dynamic Range – Log Video), widely used production & post-production format; it deserves separate explanation
- **HDR-PQ** (High Dynamic Range – Perceptual Quantizer), a foundation for **Dolby Vision**, **HDR10** and **HDR10+** formats
- **HDR-HLG** (High Dynamic Range – Hybrid Log Gamma), a sort of "halfway house" between SDR and HDR-LOG

All displays convert R, G and B **S**ignal **L**evel (**SL**) to **L**ight **L**evel (**LL**) in accordance with their specified **E**lectro-**O**ptical **T**ransfer **F**unction (**EOTF**).
E.g. the SDR EOTF is LL = SL^{DG}, DG (Display Gamma) = 2.2 or 2.4. Unlike the **CIE Brightness**, the **Perceived Light Level** = EOTF(max(R,G,B)).



*Note: The **numerical value** of Perceived Light Level in **nits** is equal to the display screen **CIE photometric brightness** in **cd/m^2** (weighted sum of R, G and B light outputs) **only** on shades of **Gray**. For any **other color** the **PLL** value in nits is **greater**. For the saturated Blue colors the PLL value could be **more than 10 times greater** than the photometric brightness.*

Maximum (100%) signal or light **relative level** not necessarily means some specific **absolute light level** in nits; maximum light output depends on the display design.

Absolute mapping schemes work **only** for the **HDR-PQ** systems utilizing the concept of **T**arget **D**evice **M**ax **B**rightness (**TDMB**) aka "Peak PQ Image Brightness".

In HDR-PQ systems, for each TDMB nits value the Absolute Light Level values are derived by mapping the video signal values to nits via the **TDMB adjusted variant** of the *ideal* HDR-PQ EOTF curve set by standard.

HDR-PQ – Road Works Ahead

Unlike SDR, HDR-HLG and HDR-LOG, the **HDR-PQ EOTF** sets the conversion law of **relative** R, G and B **S**ignal **L**evels to **absolute L**ight **L**evels.

The standard (*ideal*) HDR-PQ EOTF curve is shown on the diagram below; the ITU-R BT.2100 standard Table 4 contains its quite complex formula.

Max **R**elative **S**ignal **L**evel (RSL = 1) refers to the Absolute Max Light Level of an *assumed ideal device* producing **10,000 nit** output.

The max output of a typical HDR display is significantly lower than 10,000 nt.

This means that the original HDR-PQ content must be produced and/or converted for **a variety** of **T**arget **D**evice **M**ax **B**rightness (TDMB) values.

Such conversion can be performed by the HDR display itself controlled by the **embedded metadata**, e.g. in HDR10+ format.

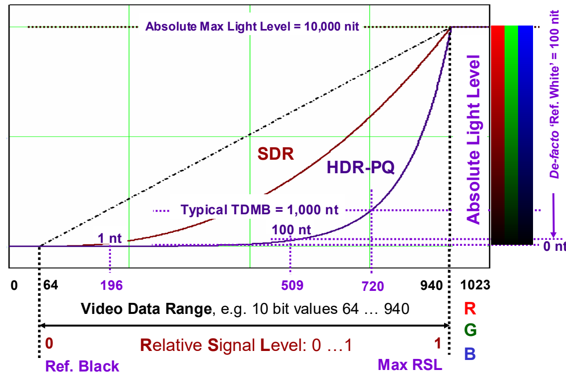
Typical TDMB is **1,000 nt**, but other values are also in use.

Note that **HDR-PQ Reference White** level (and related "Diffuse White" level) is **not yet defined**, though the *de-facto* value is thought to be between **100 nt** and **200 nt**.

Standardization of the HDR-PQ Reference White level is quite difficult because its definition as an **absolute value in nits** ("**display-referred**" approach) practically **excludes** an **outdoor production**, e.g. sport events coverage.

*A **human face reflectance is ≈ 20...40 % independent** of the **scene illumination level**.*
*With the display White set to **100 nt** the **rendered face** Light Level **must be 30 nt**.*
Sunny beach scene or dark cellar episode – always 30 nt on screen, which is nonsense.

*Return to the traditional definition of Reference White as a **"scene-referred" relative value** will **completely jeopardize** the fundamental PQ idea of **absolute light levels** reproduction.*



HDR-HLG – Halfway House or Optimal Choice?

Like SDR EOTF, the HLG EOTF converts **relative** R, G or B **S**ignal **L**evels to the **relative** Light **L**evels (traditional "**scene-referred**" approach).

The EOTF curve is shown on the diagram below; ITU-R BT.2100 standard Table 5 contains its relatively simple formula.

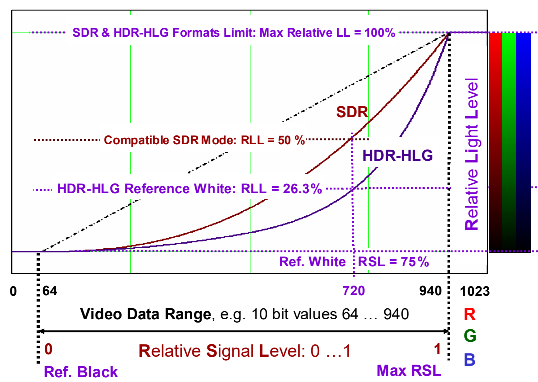
This formula combines the attenuated "2.0 gamma curve", occupying the lower 50% of the signal range until RLL = 100/12 = 8.333 % point, and a "soft knee exponential function", occupying **upper 50%** of the **signal range** and mapping it to the main **8.3%~100%** portion of the **light levels range**.

In the HLG format the Maximum Relative Light Level (RLL = 100%) is **3.8 times** higher than the Reference White Light Level (RLL = 26.3%, RSL = 75%).

The sub-range above Reference White is used mainly for specular highlights – on condition that they should not take a **significant share of the screen area**.

The max value of this share is not defined by standard. In practice the share above 5% of total screen area is thought to be a "Yellow Warning Threshold", whilst 10% is a "Red Alarm Threshold".

Unlike HDR-PQ, HLG signal can be rendered by the "old-fashioned" SDR display, though, for best results a significant adjustment of display contrast and gamma may be needed.

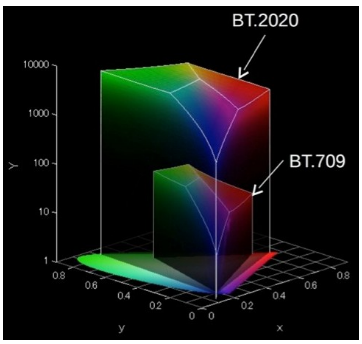


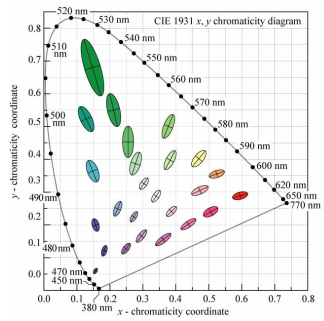
*The HDR-HLG format is promoted as backward compatible to SDR production and distribution format, not requiring any embedded metadata, but this is debatable, e.g. HLG 'Reference White' on "compatible" SDR screen comes out as **50% LL Light Gray**, much lower than **100% White**.*

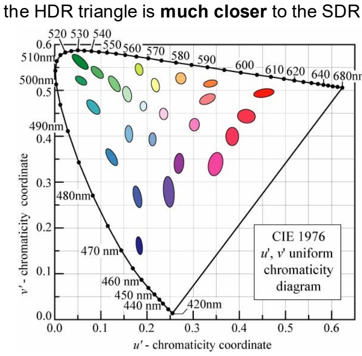
Marketing Messages & Inconvenient Truth

What's wrong with the diagram below, illustrating the differences between **HDR BT.2020** and **SDR BT-709**? Unfortunately, almost everything:

- **BT.709** standard **does not define nor require 100 nt display**. The HD SDR system relies on **relative** light levels; the SDR display max brightness is **unlimited**. Old color grading monitors (not TV!) are set up to 100 nt. Thus, from this diagram we get mildly saying "deliberate misinformation".
- **BT.2020** (in **HDR-PQ** section) allows very high light levels **only for specular highlights**, not for flat areas occupying full screen.
- In the **BT.709 HD SDR** world **full screen white** is normal practice. We should not compare "apples" with "oranges".
- As we all know, visually perceived colors with light levels about 1 nt and below collapse to **neutral gray**: "all cats are gray in the dark".
- Therefore, the **triangles** at the bottom of the diagram should shrink to one **Gray point**. This also applies to the peak light level – it must be **White**.
- The diagram uses **CIE 1931 x,y** coordinates. Years ago Mac-Adam plotted measured color vision thresholds on this **non-uniform** plane.
- On the **CIE 1976** "fair play" **uniform** diagram the green portion is smaller, and the green vertex of the HDR triangle is **much closer** to the SDR one.





Video Image Subjective Quality & HDR Color Grading

Colors change appearance depending upon **absolute luminance**, and upon **surroundings**.

Recently published **SMPTE ST 2080-3:2017** 'Reference Viewing Environment for Evaluation of HDTV Images' is the long-anticipated update to the outdated Recommended Practice document, **SMPTE RP166:1995** and outdated Recommendation **ITU-R BT.2022:2012**.
It defines a standard conditions for **comparison** and **benchmarking** of color video images **in the controlled environment**.

This should not be confused with the 'Typical TV Viewing Conditions'; e.g. Japanese NHK published several comprehensive reports on the subject.

ITU-R BT.500 'Methodology for the subjective assessment of the quality of television pictures' defines five-grade **quality** & **impairment** scales, and seven-grade **comparison** scale, as well as the important '**anchoring**' methodology. There is also a related **ITU-T P.913** standard.

A **colorist** may check the intended appearance for a master video ***assuming*** SDR EOTF 2.4-power function and display **Reference White** at 100 nits.
Currently most content is developed assuming the Reference White (related to 90% reflectance "diffuse white" aka "paper white") is at 100 nits.
However, most current monitors peak at around 250 to 300 nits and "latest and greatest" models of consumer HDR displays can go much higher.

Well-known fact is that HDR Images (and color grading procedures) suitable for a **home theater** are often not suitable for a **living room**.
Which target market is more important? Is it possible to deliver **the same** HDR content to **all types** of customers? Can embedded metadata help?

The Main Target Market for HDR Content is **?**

A. Color Grading Room

B. Home Theater

C. Living Room

About This Presentation

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For further reading we recommend wikipedia.org

About VideoQ

Company History

- Founded in 2005
- Formed by an Engineering Awards winning team sharing between them decades of global video technology.
- VideoQ is a renowned player in calibration and benchmarking of video processors, transcoders and displays, providing tools and technologies instantly revealing artifacts, problems and deficiencies, thus raising the bar in productivity and video quality experience.
- VideoQ products and services cover all aspects of video processing and quality assurance - from visual picture quality estimation and quality control to fully automated processing, utilizing advanced VideoQ algorithms and robotic video quality analyzers, including latest UHD and HDR developments.

Operations

- Headquarters in Sunnyvale, CA, USA
- Software developers in Silicon Valley and worldwide
- Distributors and partners in several countries
- Sales & support offices in USA, UK