Display Luminance Survey Initial Abstract

Luminance, “Effective-Gamma” for SDR and HDR Consumer Displays

Co-Funded by NABA, NBCUniversal, MovieLabs

DTG Zoo (UK) TV Survey

- Volunteers: BBC, Sky, NBCU, Dolby, Nick Shaw (Antler Post)
- GOAL: Determine typical TV luminance experience
  - SDR
    - Up to 53 Displays tested with up to 8 different picture modes
  - PQ & HLG (**LIMITED SAMPLE COUNT-PRELIMINARY**)
    - Up to 19 Displays tested with up to 4 different picture modes

What are we analyzing?

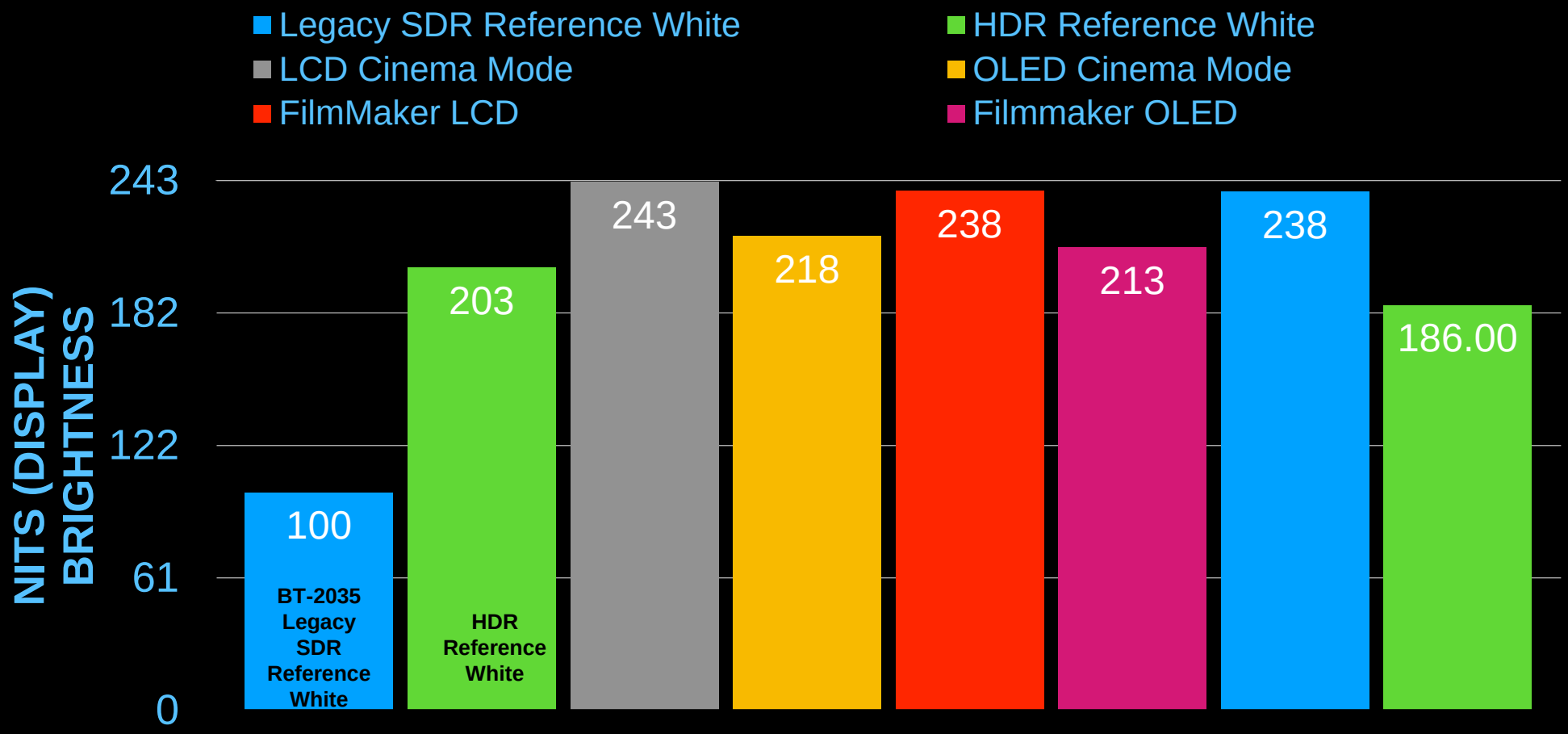
- Analysis to perform:
  - SDR TV Analysis Table (Page 6)
    - For TV Luminance Levels: What is the typical consumer viewing experience for SDR TVs vs the original reference standard?
    - What is the “effective gamma” for several TV picture modes when using the two most common HDR-to-SDR tone mappers described in ITU-R BT.2408-6 for single-master UHD production (NBCU(Hybrid-Linear) and BBC LUTs(Gamma-Adjusted))?
      - Do the two tone-mapped for HDR to SDR conversion preserve a familiar look for side-by-side display or during channel changes?
    - How are different picture modes tone-mapping in order to compensate for different room illumination?
  - PQ (PRELIMINARY) (Ideal for Live-Linear and VOD Distribution/Transmission) (Page 12)
    - Is the NATIVE absolute mapping of the PQ EOTF adhered to in Cinema/Filmmaker modes?
    - What is the effective “gamma” from black to reference white? Is the HDR signal gain-staged optimally to SDR in the focal areas?
    - Is static metadata used in HDR10 content?
    - Are highlights clipped or tone mapped when going beyond each TV’s luminance capabilities?
  - HLG (PRELIMINARY) (Common in today’s Live-Linear Production) (Page 12)
    - Is the NATIVE, relative OOTF of HLG luminance adhered to in Cinema/Filmmaker modes?
    - Does the TV tone-map HLG to keep a more consistent reference white with SDR familiar levels (~203nits)?
    - What is the effective “gamma” from 0 to 203nits(black to reference white) given the relative OOTF in HLG?

Measuring SDR “Effective Gamma” and Peak Luminance Single-Master Tone Mapping Comparisons Test Pattern

~10% Pixel Area

For for pattern set, go to Github repository here:
https://github.com/digitaltvguy/SDR-HDR-Display-Luminance-Survey

SDR TV Average Display Luminance: Picture Modes - Cinema, Filmmaker Modes, Others



SDR TV Display Modes > 2016 - Cinema, Filmmaker Modes, Others

SDR DISPLAY LUMINANCE AND "EFFECTIVE GAMMA" IN DIFFERENT PICTURE MODES

TV PICTURE MODES

Picture Modes → **Cinema** | **Filmmaker Mode** | **Factory**

TV's Manufactured At/After 2016

Display Type / Pattern Size

	Cinema: LCD Full Screen	Cinema: LCD L32	Cinema: OLED L32	Filmmaker Mode: LCD Full Screen	Filmmaker Mode: LCD L32	Filmmaker Mode: OLED L32	Factory: LCD Full Screen	Factory: LCD L32	Factory: OLED L32
Average Peak White	228.65	242.52	217.50	247.45	238.23	212.50	241.87	237.91	186.00
MAX Nominal Peak White	405.90	416.00	234.00	397.50	390.00	228.80	546.00	541.00	267.00
MIN Nominal Peak White	78.00	125.00	201.00	53.30	64.60	201.80	83.30	79.26	186.00
AVERAGE "EFFECTIVE GAMMA" using Two HDR->SDR Tone-Mapping Methods (Low Gamma = Midtone Lift) AT/AFTER 2016									
Average Calculated Hybrid-Linear L32	2.25	2.42	2.22	2.33	2.27	2.42	2.16	1.93	
MAX Calculated Hybrid-Linear L32	2.66	2.72	2.22	2.48	2.53	2.54	2.96	2.55	0.00
MIN Calculated Hybrid-Linear L32	0.33	2.20	2.22	2.13	1.72	2.29	1.14	0.84	0.00
Average Calculated Gamma-Adjusted L32	2.00	2.08	1.95	1.94	2.11	2.11	1.86	1.75	1.33
MAX Calculated Gamma Adjusted L32	2.31	2.29	1.95	1.94	2.18	2.18	2.49	2.29	1.33
MIN Calculated Gamma-Adjusted L32	0.70	1.94	1.95	1.93	2.02	2.02	1.02	0.90	1.33
Sample Count	27	26	2	6	6	3	30	30	2

Traditional Reference Display Luminance: 100 — Reference Gamma: 2.4 — HDR/SDR Unified Reference White Level: 203

Rough Gamma Measurement (Identify midtown lift) ≥ 2016 (Additional Picture Modes)

	Standard	Sports	Vivid	ISF Dark Room	ISF Bright Room
Effective Gamma Hybrid-Linear L32	1.95	1.79	1.92	2.33	2.05
Effective Gamma Gamma-Adjusted L32	1.71	1.44	1.67	2.03	1.78

Traditional SDR Reference Displays: 100

Unified Reference White: 203

Calculating for BT.1886 (Gamma 2.4 or Optimal Gain-Staging)

Log << MidGray cd/m²>/<Graphic White cd/m²> / Log <% of signal level of measured gray> = <Rough Gamma Level>

EXAMPLE: LOG(26/203)/LOG(0.424658) = 2.4

A lower system gamma indicates a lifted gamma (higher shadows and midtones)

Average Peak White

Max Peak White

Min Peak White

Hybrid-Linear HDR->SDR (Mimics BT.1886 - Linear Scaling)

"Gamma-Adjusted" HDR->SDR (Lifts Shadows and Midtones)

Sample Count

"Single-Master" Tone Mappings

Hybrid-Linear HDR->SDR (Mimics BT.1886 - Linear Scaling)

"Gamma-Adjusted" HDR->SDR (Lifts Shadows and Midtones)

"Effective Gamma" Other Picture Modes

"Single-Master" Tone Mappings

"Effective-Gamma" Formula

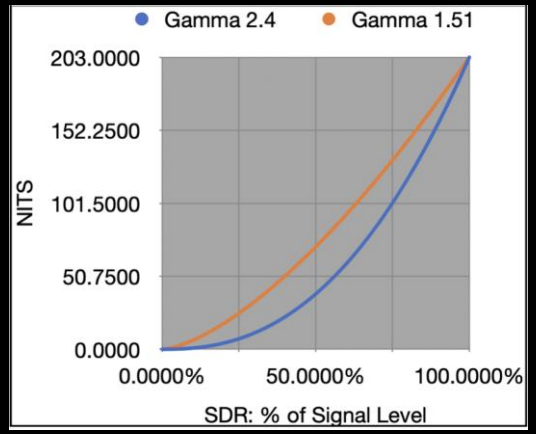
Simulations of Experience:
Original, Vivid 200nit, Vivid 100nit

HDR Original & SDR Filmmaker Modes
1,000nit normalized HLG
SDR Peak White = 203nits
Reference White = 203nits

Vivid Mode (SDR @200nits)
(Hybrid) Linear down mapping
Vivid Mode has a built-in Midtone Boost
There is some bleaching of skin tones

Vivid Mode (SDR @ 200nits)
Gamma-Adjusted down mapping
Has a built-in midtone boost
Vivid Mode has a built-in Midtone Boost
Together, they additively bleach skin tones

Picture Modes and Midtone Shifts



This example shows a reference gamma of 2.4 but also gamma 1.51 in Vivid Mode while using a “Gamma-Adjusted” down mapping.

Left = NITS

Bottom = Signal Level

The “Vivid” Picture Mode pushes midtones up to raise the average luminance but doesn’t shift the peak white level.

Calculating “Effective Gamma”
Is the Display Stretching or Compressing Shadows & Midtones?

- Goal: Determine optimal gain-staging and/or any gamma stretching that may be occurring in different picture modes.
- Using a simple calculation we can compare the luminance of midgray against peak white, and generate an “effective gamma”. A value of 2.4 identifies optimal gain-staging from source to display.
- Any value below/above 2.4 identifies gamma stretching/compression of shadows and midtones.
- Most older TVs in a “Cinema mode” default to using a gamma 2.2 display rendering and therefore a slightly higher average luminance versus the original contents intent. A gamma 2.2 display is optimized for brighter viewing environments.
- After 2020, by default, some products started to properly support the reference SDR EOTF ITU-R BT.1886 in Cinema/Movie/Filmmaker picture modes. BT.1886 uses gamma 2.4 and therefore provides more optimal gain-staging with the original content.
- Many TVs now support BT.1886 as an option even if they are not the default.

PRELIMINARY
SUMMARY
HDR PICTURE MODE ANALYSIS

CONSUMER TV LUMINANCE
AND
EFFECTIVE HDR FORMAT RENDERING

Goals: HDR Picture Mode Analysis

- Determine HDR TV Luminance in 3 picture modes using specific test patterns
  - **Measure MidGray** - Full Screen, L32(10% pixel area)
  - **Graphic White** - 75% signal level - Full-Screen, L32(10% pixel area)
  - 1,000nit White HLG/PQ - L32(10% Pixel Area)
  - 4,000nit White PQ-Only - L32(10% Pixel Area)
- Calculate Graphic White Avg/Max/Min
- Calculate “Effective-Gamma” using midgray vs reference white
  - For HLG, which is relative, it must be done using the full variable-gamma OOTF. HLG applies a midtone adjustment based on the peak-white luminance capability of the display which shifts gamma from 2.4.
  - For PQ, which is absolute, the “effective gamma” of the EOTF should always be 2.4.
- Using the “Effective-Gamma” we calculate the deviation from a HLG or PQ format reference.
- Bottom right contains HLG’s reference OOTF expected values and “effective-gamma”.
- For the PQ 4,000nit pattern, the HEVC reference file contains SEI messages to determine if HDR10 is being used to prevent clipping.

***VERY PRELIMINARY - LIMITED SAMPLE COUNT**
HDR TV Display Modes: Cinema, Filmmaker Modes, Others

Picture Modes
Display TypePattern Size

Average Ref. White
Max Ref. White
Min Ref. White

Deviation from Standard OOTF

"Effective-Gamma"
From black to reference white

Average Peak White
Max Peak White
Min Peak White

Absolute
Effective Gamma
PQ EOTF Reference

	PQ DISPLAYS ≥ 2020							HLG DISPLAYS ≥ 2020						
	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES	AVERAGES
	Factory Mode	Factory Mode	Cinema Mode	Cinema Mode	Filmmaker Mode	Filmmaker Mode	Filmmaker Mode	Factory Mode	Factory Mode	Cinema Mode	Cinema Mode	Filmmaker Mode	Filmmaker Mode	Filmmaker Mode
	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32
	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020
	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	OLED ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	LCD Backlit ONLY	OLED ONLY
	Measured Luminance & Effective Gamma (For gain-staging from black to reference white)													
Graphic White Average		199.05	188.25	208.58	194.70	220.25	222.34		159.00	119.60	151.37	140.00	144.95	222.34
Graphic White MAX		344.70	235.50	250.00	231.80	493.50	260.00		200.00	139.00	246.00	140.00	245.00	260.00
Graphic White MIN		115.00	141.00	147.00	157.60	68.00	190.40		118.00	109.80	79.50	140.00	65.00	190.40
	PQ "Effective Gamma" (2.4) deviation Black to Reference White (38-58%) Higher Numbers represent a midtone lift Lower numbers represent a midtone compression							HLG "Effective Gamma" deviation from Reference OOTF Black to Reference White (38-75%) NIT Offsets thru BT.2100 Formula. Higher Numbers represent a midtone lift Lower numbers represent a midtone compression						
		22.87%	9.20%	7.23%	1.00%	5.99%	-1.48%		28.05%	-0.81%	2.65%	-1.38%	-1.38%	-3.84%
	PQ "Effective Gamma" is fixed at 2.4							HLG "Effective-Gamma" is variable. Averages are not valid.						
		1.87	1.93	2.20	2.37	2.25	2.43	NA	NA	NA	NA	NA	NA	NA
	A lower system gamma indicates a lifted gamma (higher shadows and midtones) from black to Reference White													

	LCD Backlit L32 or 5%		LCD Backlit L32		LCD Backlit L32		OLED L32	LCD Backlit L32		LCD Backlit L32		LCD Backlit L32		OLED L32
Maximum Peak White	1353		1027		1935.00		1001	1434.00		1297		1285		1285
Minimum Peak White	230		177.8		215.00		701	312.60		177.1		210.00		177.1
Average Peak White	638.23		554.03		753.25		808.18	611.93		578.49		583.67		803.18
COUNT	15		8		6		6	18		12		6		6

Sample Count

PQ Effective Gamma (Reference)	HLG Displays with Different Peak Brightness Capabilities						
	400	600	1000	2000	3000	4000	Peak White
203.7	0.00	0.00	0.00	0.00	0.00	0.00	Black Level
25.7	1.03	1.11	1.20	1.33	1.40	1.45	HLG Variable System Gamma
0	101.46	137.95	203.15	343.50	467.04	580.80	*Graphic White*
2.42	2.06	2.21	2.40	2.65	2.80	2.90	"Effective Gamma"
	17.33	20.76	26.07	35.51	42.54	48.36	MidGray

"Single-Master"
Tone Mappings

Relative
"Effective Gamma"
From Black-to-Ref White
HLG OOTF Reference