

Display Luminance Survey Initial Abstract

Luminance, “Effective-Gamma” for SDR and HDR Consumer Displays
Co-Funded by NABA, MovieLabs, NBCUniversal

Effort @ DTG Zoo (UK)

- Volunteers from BBC, Sky, NBCU, Dolby, Cromorama
- Determine TV luminance experience and perform “rough” gain-staging analysis for SDR and HDR TV Picture Modes.
 - 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

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



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

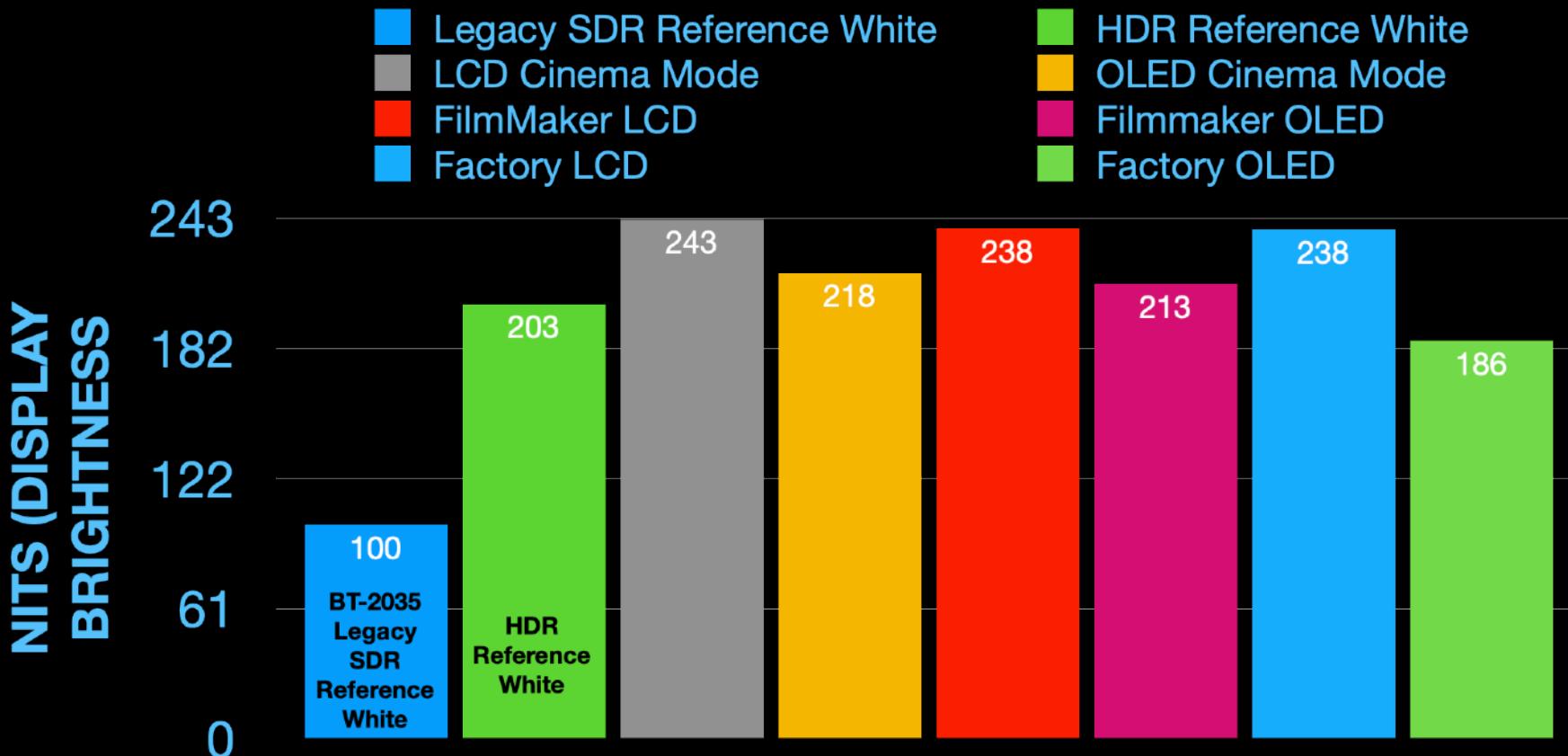
Goals and Analysis

- Determine luminance experience for SDR and HDR viewers
 - SDR (Table Page 5)
 - How much brighter is todays SDR viewing experience?
 - What is the “effective gamma” using two HDR to SDR tone mappers used for single-master UHD production (NBCU(Hybrid-Linear) and BBC LUTs(Gamma-Adjusted))
 - “Hybrid-Linear” - Mimics BT.1886 linear scaling of HDR to SDR from black to reference white that optimizes converted SDR for typically higher luminance viewing on consumer TV’s.
 - “Gamma-Adjusted” - Applies a “gamma-adjusted” scaling of HDR to SDR from black to reference white that optimizes converted SDR for 100nit displays.
 - Both methods use a subjective knee to compressed HDR highlights into SDR
 - PQ (**PRELIMINARY**)
 - Is the NATIVE absolute mapping of PQ luminance adhered to in Cinema/Filmmaker modes?
 - Is static metadata used from HDR10
 - Are highlights clipped or tone mapped when beyond the TV’s capabilities?
 - What is the effective “gamma” from 0 to 203nits (does it map easily to SDR?)?
 - HLG (**PRELIMINARY**)
 - Is the NATIVE relative mapping (Full OOTF) of HLG luminance adhered to in Cinema/Filmmaker modes?
 - What is the effective “gamma” from 0 to 203nits (does it map easily to SDR?)?

What are we analyzing?

- Determine luminance experience for SDR and HDR viewers
 - SDR (Table Page 5)
 - How much brighter is todays SDR viewing experience?
 - What is the “effective gamma” of TV picture modes when using two HDR-to-SDR tone mappers used for single-master UHD production (NBCU(Hybrid-Linear) and BBC LUTs(Gamma-Adjusted))
 - PQ (PRELIMINARY)
 - Is the NATIVE absolute mapping of the PQ EOTF adhered to in Cinema/Filmmaker modes?
 - Is static metadata used from HDR10?
 - Are highlights clipped or tone mapped when beyond each TV’s luminance capabilities?
 - What is the effective “gamma” from black to reference white (is it gain-staged correctly to SDR?)?
 - HLG (PRELIMINARY)
 - Is the NATIVE relative OOTF of HLG luminance adhered to in Cinema/Filmaker 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 given the relative OOTF in HLG?

SDR TV Display 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			Filmmaker Mode			Factory					
Picture Modes	Cinema			Filmmaker Mode			Factory					
TV's Manufactured At/After 2016												
Display Type	LCD Full Screen	LCD L32	OLED L32	LCD Full Screen	LCD L32	OLED L32	LCD Full Screen	LCD L32	OLED L32			
Pattern Size	Avg Nominal Peak White	228.65	242.52	217.50	247.45	238.23	212.50	241.87	237.91	186.00		
Average Peak White	Max Nominal Peak White	405.90	416.00	234.00	397.50	390.00	228.80	546.00	541.00	267.00		
Max Peak White	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												
Hybrid-Linear HDR->SDR (Mimics BT.1886 - Linear Scaling)	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		
"Gamma-Adjusted" HDR->SDR (Lifts Shadows and Midtones)	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:			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	Traditional SDR Reference Displays	100					
Effective Gamma Gamma-Adjusted L32	1.71	1.44	1.67	2.03	1.78	Unified Reference White	203					
Calculating for BT.1886 (Gamma 2.4 or Optimal Gain-Staging) $\log \left(\frac{\text{MidGray cd/m}^2}{\text{Graphic White cd/m}^2} \right) / \log \left(\frac{\% \text{ signal level of measured gray}}{\% \text{ signal level of measured white}} \right) = \text{Rough Gamma Level}$												
EXAMPLE: $\log(26/203) / \log(0.424658) = 2.4$												
A lower system gamma indicates a lifted gamma (higher shadows and midtones)												

"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

Original, Vivid 200, Vivid 100



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



Vivid Mode (SDR @ 200nits)
(Hybrid) Linear down mapping

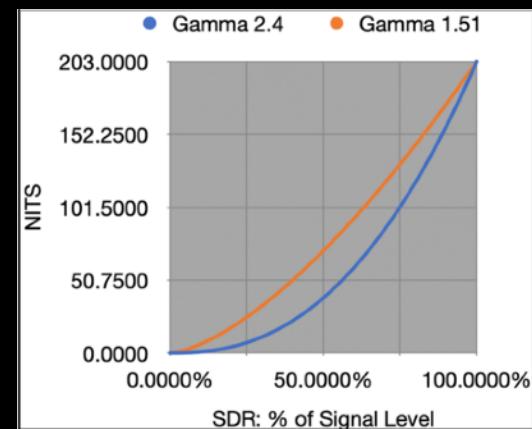


Vivid Mode (SDR @ 200nits)
Gamma-Adjusted down mapping

Rough “Effective Gamma” Calculation

Is the Display Stretching or Compressing Shadows & Midtones?

- Getting a rough idea of 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 would identify optimal gain-staging from source to display.
- Any value below/above 2.4 could roughly identify gamma stretching/compression of shadows and midtones.
- Most older TV’s in a “Cinema mode” defaulted to gamma 2.2 and rendered a slightly higher average luminance version of the original content. Theoretically this display is optimized for brighter viewing environments.
- After 2020 some products started to support BT.1886(Gamma 2.4) by default.



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

****PRELIMINARY****

SUMMARY

HDR RESULTS

CONSUMER TV LUMINANCE SURVEY

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

PQ DISPLAYS ≥ 2020							HLG DISPLAYS ≥ 2020						
	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
	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32	L32	Full Screen	L32	Full Screen	L32	Full Screen
	≥ 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	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	199.40		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													
	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													
	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	LCD Backlit L32	LCD Backlit L32	LCD Backlit L32	LCD Backlit L32	LCD Backlit L32	OLED L32
Maximum Peak White	LCD Backlit L32 or 5%	LCD Backlit L32	LCD Backlit L32	OLED L32	1353	1027	1935.00	1001	1434.00	1297	1285	1285	
Minimum Peak White	230	177.8	215.00	701					312.50	177.1	210.00	177.1	
Average Peak White	638.23	554.03	753.25	508.18					611.33	578.49	583.67	863.18	
COUNT	15	8	6	6					18	12	6	6	6
							HLG Displays with Different Peak Brightness Capabilities						
							400	600	1000	2000	3000	4000	Peak White
							0.00	0.00	0.00	0.00	0.00	0.00	Black Level
							1.03	1.11	1.20	1.33	1.40	1.45	HLG Variable System Gamma
							101.46	137.95	203.15	343.50	467.04	580.80	Graphic White
							2.06	2.21	2.40	2.85	2.80	2.90	"Effective Gamma"
							17.33	20.76	26.07	35.51	42.54	48.36	MidGray

“Single-Master” Tone Mappings

— Sample Count

Absolute Effective Gamma PQ EOTF Reference