

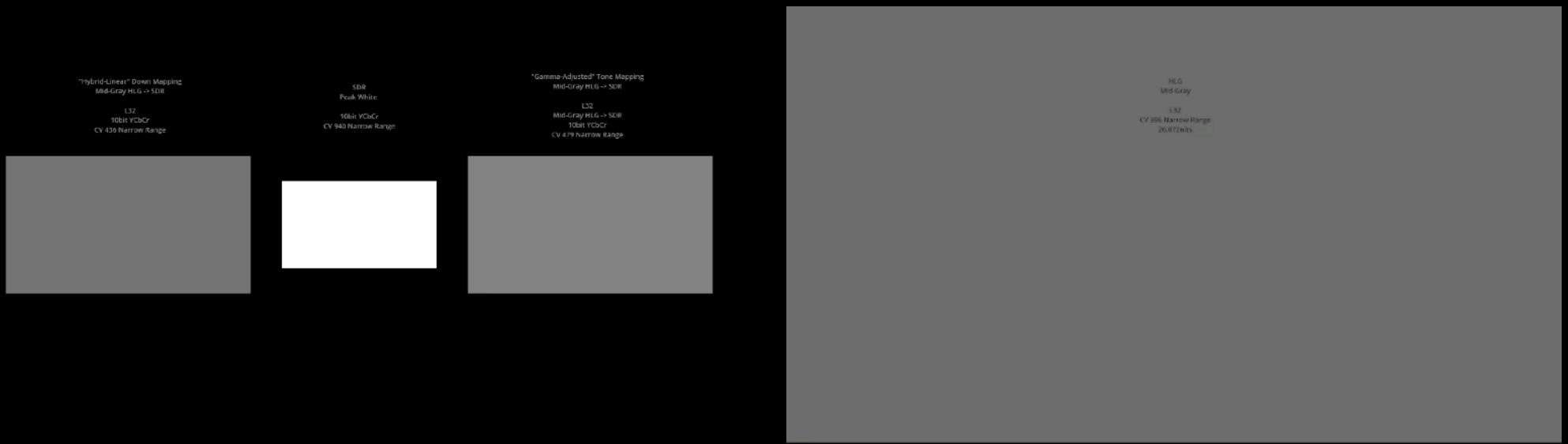
Display Luminance Survey Initial Abstract

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

Effort @ DTG Zoo (UK)

- Volunteers: BBC, Sky, NBCU, Dolby, Nick Shaw(Antler Post)
- 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

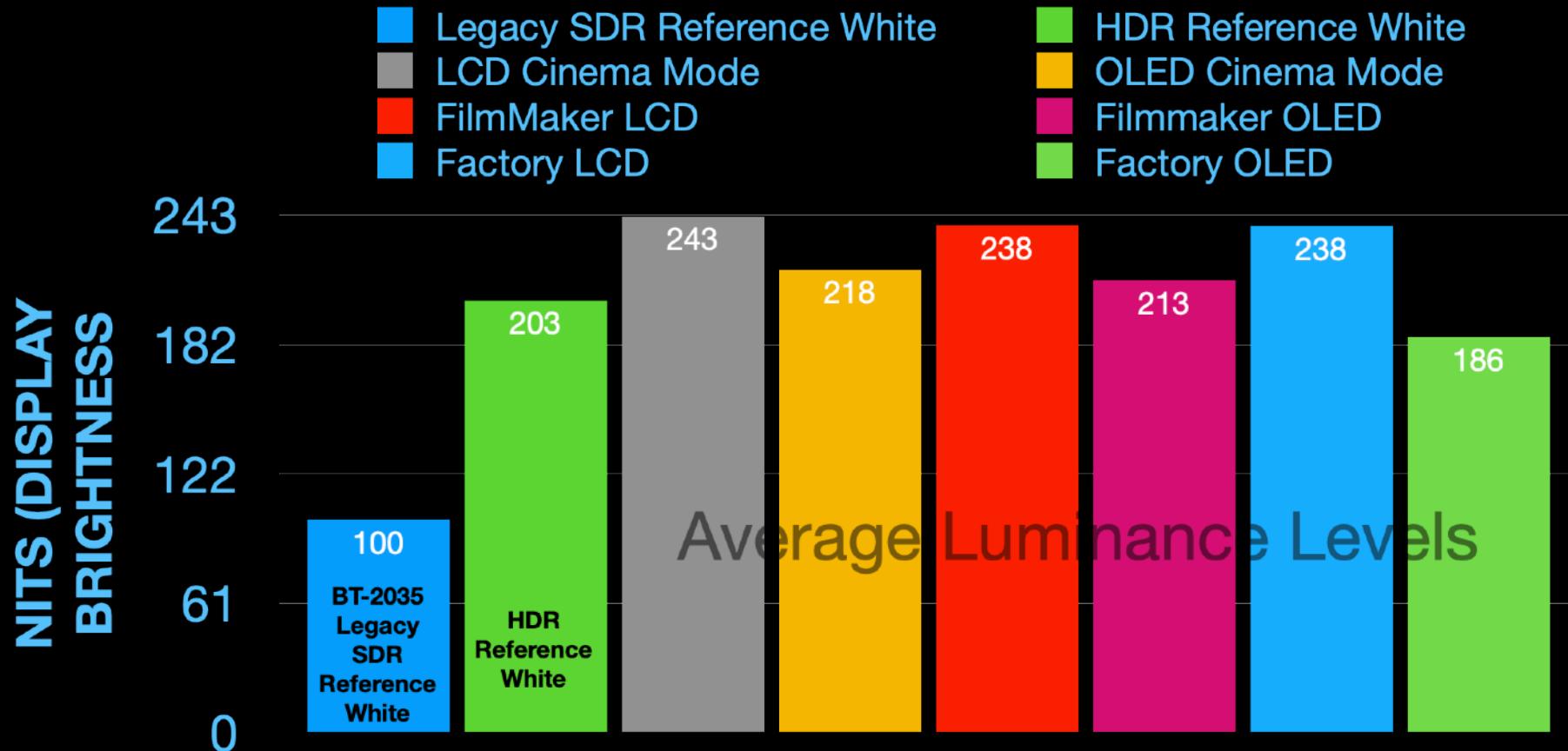


For full pattern set, go to Github repository here:
<https://github.com/digitaltvguy/SDR-HDR-Display-Luminance-Survey>

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/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 given the relative OOTF in HLG?

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			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		Traditional SDR Reference Displays	100		
Effective Gamma Hybrid-Linear L32	1.95	1.79	1.92	2.33	2.05		Unified Reference White	203		
Effective Gamma Gamma-Adjusted L32	1.71	1.44	1.67	2.03	1.78					
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

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	LCD	OLED	LCD	LCD	OLED	LCD	LCD	OLED			
Pattern Size	Full Screen	L32	L32	Full Screen	L32	L32	Full Screen	L32	L32			
Average Peak White	AVG Nominal Peak White	228.65	242.52	217.50	247.45	238.23	212.50	241.87	237.91	186.00		
Max Peak White	MAX Nominal Peak White	405.90	416.00	234.00	397.50	390.00	228.80	546.00	541.00	267.00		
Min 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			
	MIN Calculated Hybrid-Linear L32	0.33	2.20	2.22	2.13	1.72	2.29	1.14	0.84			
	Average Calculated Gamma-Adjusted L32	2.00	2.08	1.95	1.94	2.11	2.11	1.86	1.75			
"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			
	MIN Calculated Gamma-Adjusted L32	0.70	1.94	1.95	1.93	2.02	2.02	1.02	0.90			
	Sample Count	27	26	2	6	6	3	30	30			
	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)												
Effective Gamma Hybrid-Linear L32	Standard	Sports	Vivid	ISF Dark Room	ISF Bright Room							
	1.95	1.79	1.92	2.33	2.05							
	Unified Reference White	100										
	Effective Gamma Gamma-Adjusted L32	1.71	1.44	1.67	2.03	1.78						
Calculating for BT.1886 (Gamma 2.4 or Optimal Gain-Staging) $\text{Log} \left(\frac{\text{MidGray cd/m}^2}{\text{Graphic White cd/m}^2} \right) / \text{Log} \left(\frac{\% \text{ signal level of measured gray}}{\text{Rough Gamma Level}} \right) = \text{EXAMPLE: } \text{LOG}(26/203)/\text{LOG}(0.424658) = 2.4$												
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

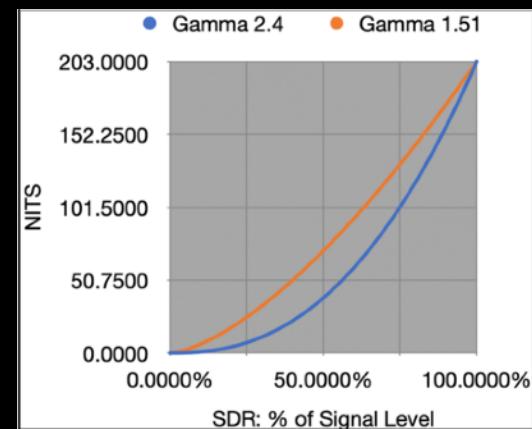


Vivid Mode (SDR @ 200nits)
Gamma-Adjusted down mapping

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													
Picture Modes	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
Display Type	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32	Full Screen	L32	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	
Pattern Size	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020	≥ 2020		
Average Ref. White	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	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	
Max Ref. White	344.70	235.50	250.00	231.80	493.50	260.00	200.00	139.00	246.00	140.00	245.00	Graphic White MAX													
Min Ref. White	115.00	141.00	147.00	157.60	68.00	199.40	118.00	109.80	79.50	140.00	65.00	Graphic White MIN													
Deviation from Standard (Mimics BT.1886 - Linear Scaling)	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%) NTT Offsets thru BT.2100 Formula. Higher Numbers represent a midtone lift Lower numbers represent a midtone compression												
"Effective-Gamma" From black to reference white	22.87%	9.20%	7.23%	1.00%	5.99%	-1.48%	28.05%	-0.81%	2.65%	-1.38%	-1.38%	PQ "Effective Gamma" is fixed at 2.4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Average Peak White	1.87	1.93	2.20	2.37	2.25	2.43	NA	NA	NA	NA	NA	Maximum Peak White	1353	1027	1935.00	1001	1434.00	1297	1285	1285	1285	1285	1285	1285	1285
Max Peak White	230	177.8	215.00	701	312.60	177.1	210.00	177.1	210.00	177.1	177.1	Minimum Peak White													
Min Peak White	638.23	554.03	753.25	808.18	611.93	578.49	583.67	583.67	803.18	803.18	803.18	Average Peak White													
COUNT	15	8	6	6	18	12	6	6	6	6	6	HLG Displays with Different Peak Brightness Capabilities													
PQ Effective Gamma (Reference)	400	600	1000	2000	3000	4000	Peak White	0.00	0.00	0.00	0.00	203.7	0.00	1.11	1.20	1.33	1.40	1.45	Black Level	1.03	2.21	2.40	2.65	2.80	2.96
	101.46	137.95	203.15	343.50	467.04	580.80	Graphic White	101.46	137.95	203.15	343.50	25.7	101.46	137.95	203.15	343.50	467.04	580.80	Graphic White	2.06	2.21	2.40	2.65	2.80	2.96
	17.33	20.76	26.07	35.51	42.54	48.36	MidGray	17.33	20.76	26.07	35.51	0	17.33	20.76	26.07	35.51	42.54	48.36	MidGray	2.42	2.65	2.80	2.96	3.12	3.28

"Single-Master"
Tone Mappings

Sample Count

Absolute Effective Gamma
PQ EOTF Reference

Relative Effective Gamma
HLG OOTF Reference