Color Volume Accuracy Measurement Techniques

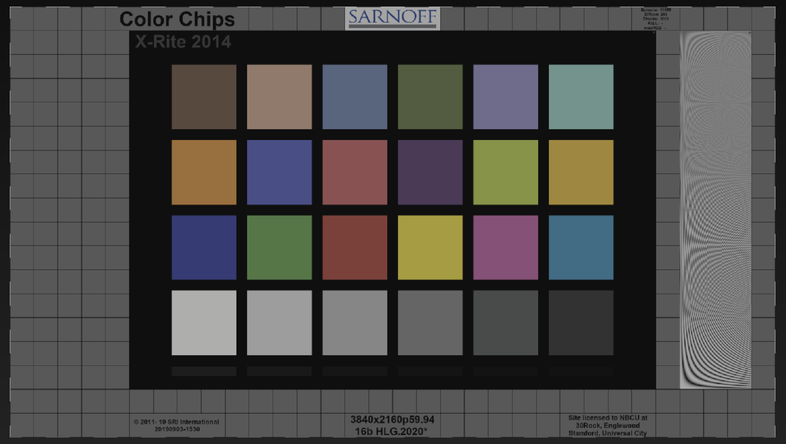
Please contact chris.seeger@nbcuni.com- NBCUniversal Advanced Technology 2020 with any questions (June 17th, 2020)

Test Patterns in HLG, PQ, SDR

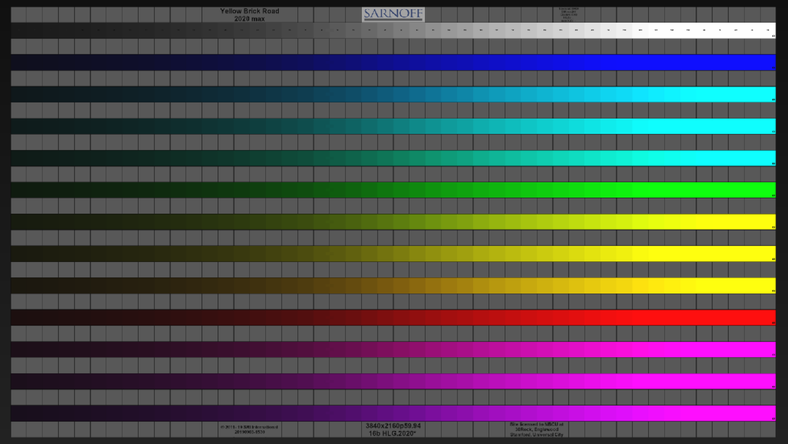
1. BT.2111 Test Patterns in HLG, PQ, SDR will be used to measure basic basic light-levels and for a basic view of color
2. Sarnoff Yellow-Brick-Road patterns will be used to sample and plot 492 levels of colorfulness for color primaries and compound colors.
3. XRite Colorchecker 2014 patterns will be used to check BT.709 colors that may be native or “containerized” in other transfer functions and color spaces.

Test Patterns in HLG, PQ, SDR

XRite Colorchecker 2014



Sarnoff YBR



BT.2111 Colorbars

Getting the Tools

- Vooya Video Player ($29.99)
    - https://www.offminor.de/downloads.html
- Vooya ycctoicc plug-in ($250)
    - http://sites.fastspring.com/offminor/product/ycciccsee
- Vooya QuickTime Plug-In (Free)
    - https://www.dropbox.com/s/ier3r2vlw3e96ln/Vooya_voo%2BPlug-Ins_061620.zip?dl=1
- Sarnoff CSM Test Patterns: https://www.sri.com/video-test-measurement
- Coordinates for Sarnoff and EBU patterns (eliminates the need to manually gather test pattern coordinates).
    - https://www.dropbox.com/personal/__PERMALINKS/Vooya-Plotting-Coordinates
- BT2111 Reference Patterns (HLG, PQ, SDR)
    - https://www.dropbox.com/sh/o4hccqqxlwc3ywj/AACjG412uUccf2gdV5FUoAvva?dl=1

Vooya Installation

1. Copy “Vooya” app into /Applications Folder
2. Plug-Ins
    - Unzip Plug-Ins Folder and put in a place of your choice
    - Install libYccIccSee.dylib file in plug-ins folder
3. Run Vooya and install license
4. Click “Plug-Ins” pulldown menu and “Set Plugin Directory” to location of the plug-ins folder previously installed.

Media Attributes

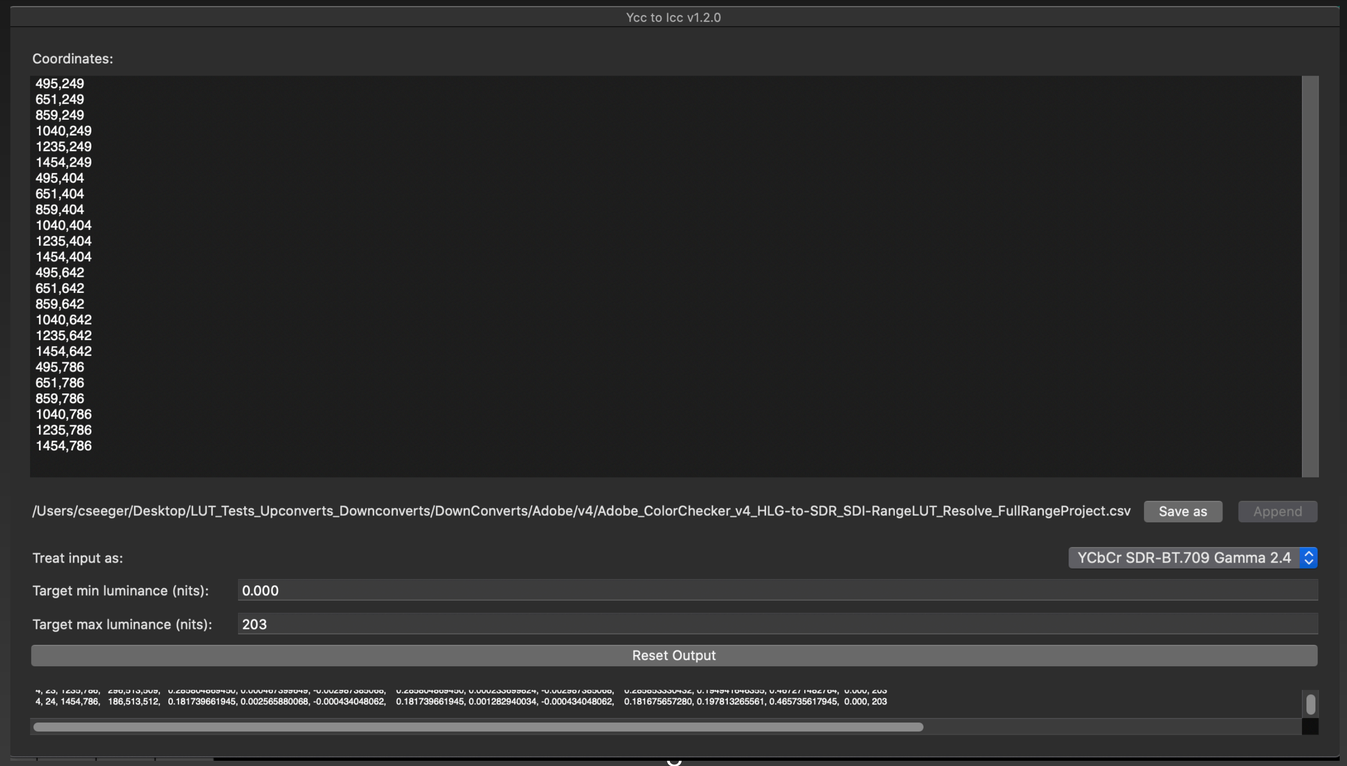
- QuickTime wrapped only
- Currently supported on Mac OSX only because of Vooya's use of "AVFoundation"
- ProRes or v210-Uncompressed 10/12-bit codecs.
- PQ-BT.2100, HLG-BT.2100, SDR-BT.709 Transfer Functions/Color Spaces.
- NCLC color tags will be ignored. Vooya does not color manage it's preview display and reads raw YCbCr/RGB data.
- Calculations currently only support YCbCr conversions

Gather Coordinates of Test Pattern Part 1

- Open QuickTime movie with test pattern to gather coordinates
- Click “M” key to turn on “Magnifier”
- Move the “Magnifier” around the screen. Coordinates are shown on the upper left of the magnifier
- Record the coordinates in the format X,Y and a carriage return after every entry into a text file with an appropriate name (HLG-Original, HLG-to-SDR, etc) and a “.csv” extension.

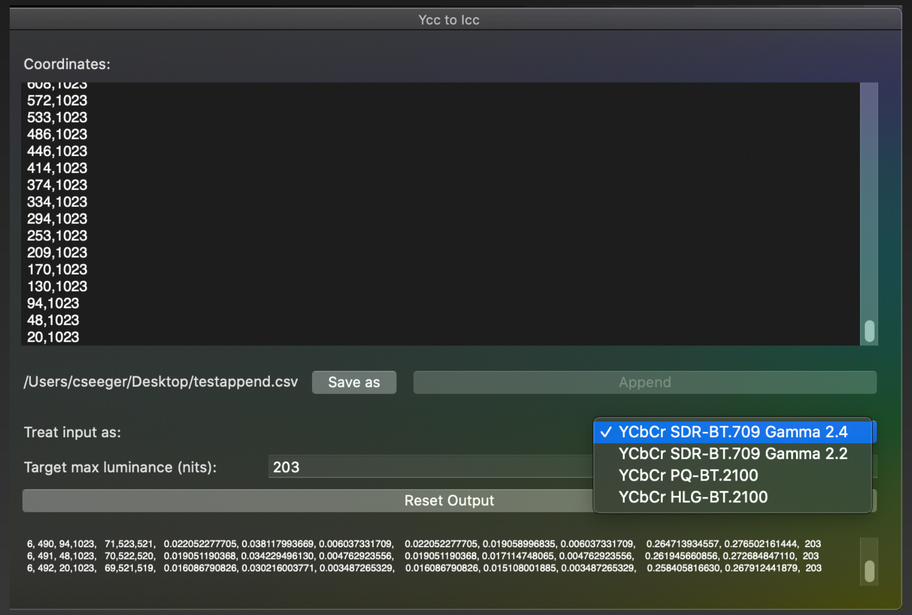
Using the Vooya Plug-In Part 1

1. Open “Vooya” and click the “Tools” menu and select “Ycc to Icc” to open the conversion plugin.
2. Copy/Paste coordinates previously gathered from the test pattern into the “Coordinates” window.
3. For SDR, settings should be SDR Gamma 2.4, max: 203nits, min: 0
4. For HLG, settings should be luminance max nits: 1000



Using the Vooya Plug-In Part 2

1. Click on “Treat Input as:” menu pulldown and select the movies transfer function, color space, Gamma.
2. Click “Save As” to save a csv output of the ICtCp, ITP & u’v’ results.



Using the Vooya Plug-In Part 3

1. Copy T/P or u’v’ results (see example below) into any plotting software including Apple Numbers or MS Excel as a simple X/Y.

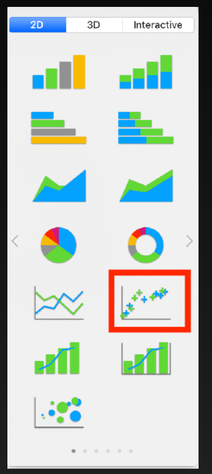
Frame	Pixel Nr.	x	y	Y	Cb	Cr	I	Ct	Cp	I	T	P	u'	v'	nits
6	1	1625	145	0	512	512	0.000000730956	0.000000000000	0.000000000000	0.000000730956	0.000000000000	0.000000000000	0.197830006643	0.468319994939	203
6	2	1581	145	120	998	473	0.370191363466	0.272528164573	-0.164381133767	0.370191363466	0.136264082287	-0.164381133767	0.175445108682	0.157837671384	203
6	3	1544	145	118	974	475	0.359765096822	0.270204450535	-0.162215147127	0.359765096822	0.135102225268	-0.162215147127	0.175444509108	0.157844724358	203
6	4	1501	145	116	960	476	0.353303256659	0.268703840631	-0.160837191083	0.353303256659	0.134351920315	-0.160837191083	0.175444722088	0.157841663576	203
6	5	1462	145	114	941	477	0.344477447441	0.266563766718	-0.158899350943	0.344477447441	0.133281883359	-0.158899350943	0.175443980509	0.157845642230	203
6	6	1420	145	111	921	479	0.334653991714	0.264074711477	-0.156677918200	0.334653991714	0.132037355739	-0.156677918200	0.175445012667	0.157836952191	203
6	7	1383	145	109	902	481	0.325231653003	0.261560572446	-0.154469291845	0.325231653003	0.130780286223	-0.154469291845	0.175445386371	0.157837090269	203
6	8	1337	145	107	883	482	0.315495363043	0.258829870148	-0.152110018071	0.315495363043	0.129414935074	-0.152110018071	0.175444554753	0.157841733327	203
6	9	1301	145	105	864	484	0.305418597553	0.255864828504	-0.149585259052	0.305418597553	0.127932414252	-0.149585259052	0.175444887598	0.157842080526	203
6	10	1263	145	102	843	485	0.293624050232	0.252203842833	-0.146523653892	0.293624050232	0.126101921416	-0.146523653892	0.175444568036	0.157837843751	203
6	11	1220	145	100	824	487	0.282741715739	0.248631128703	-0.143583104157	0.282741715739	0.124315564352	-0.143583104157	0.175445100577	0.157838198224	203
6	12	1181	145	98	802	489	0.269709958963	0.244091187146	-0.139914652066	0.269709958963	0.122045593573	-0.139914652066	0.175444639062	0.157844936610	203
6	13	1141	145	94	774	491	0.251722173614	0.237349601931	-0.134591646722	0.251722173614	0.118674800965	-0.134591646722	0.175445446275	0.157834115444	203
6	14	1101	145	92	756	492	0.239741679620	0.232514117829	-0.130857930998	0.239741679620	0.116257058914	-0.130857930998	0.175444350578	0.157838211207	203
6	15	1062	145	89	731	494	0.222137991329	0.224887066749	-0.125092462644	0.222137991329	0.112443533374	-0.125092462644	0.175444390267	0.157835710103	203
6	16	1013	145	87	707	496	0.204512057050	0.216552498509	-0.118952045131	0.204512057050	0.108276249255	-0.118952045131	0.175443314544	0.157852002356	203
6	17	970	145	84	685	498	0.186829942483	0.207447597792	-0.112418662199	0.186829942483	0.103723798896	-0.112418662199	0.175444633394	0.157840512133	203
6	18	929	145	82	667	500	0.171702169147	0.198982050769	-0.106493032823	0.171702169147	0.099491025384	-0.106493032823	0.175445783520	0.157836644724	203
6	19	894	145	80	651	501	0.157436896922	0.190366535427	-0.100602617370	0.157436896922	0.095183267713	-0.100602617370	0.175445659575	0.157835176933	203
6	20	845	145	78	635	502	0.142412583962	0.180556024119	-0.094054956638	0.142412583962	0.090278012059	-0.094054956638	0.175445059260	0.157832715545	203
6	21	809	145	77	622	503	0.129919586010	0.171743854714	-0.088308933682	0.129919586010	0.085871927357	-0.088308933682	0.175443340067	0.157852586751	203
6	22	779	145	75	610	504	0.117278459921	0.162187523259	-0.082217352816	0.117278459921	0.081093761629	-0.082217352816	0.175445358521	0.157825202165	203
6	23	732	145	74	597	505	0.103600504410	0.150963371872	-0.075240154974	0.103600504410	0.075481685936	-0.075240154974	0.175443268992	0.157851223876	203
6	24	691	145	73	590	506	0.095677626134	0.144023066600	-0.071017201262	0.095677626134	0.072011533300	-0.071017201262	0.175446337530	0.157832206929	203
6	25	647	145	72	581	506	0.085346689688	0.134380865340	-0.065274315493	0.085346689688	0.067190432670	-0.065274315493	0.175440486259	0.157849139856	203
6	26	608	145	71	574	507	0.076909422407	0.125990768702	-0.060375700681	0.076909422407	0.062995384351	-0.060375700681	0.175445794788	0.157826999668	203
6	27	572	145	70	567	508	0.068230452936	0.116795960143	-0.055122553562	0.068230452936	0.058397980071	-0.055122553562	0.175452030110	0.157786594090	203
6	28	533	145	70	561	508	0.061180815818	0.108796581503	-0.050655446329	0.061180815818	0.054398290752	-0.050655446329	0.175442012361	0.157866840292	203
6	29	486	145	69	556	508	0.054506819719	0.100811544912	-0.046288351559	0.054506819719	0.050405772456	-0.046288351559	0.175435783043	0.157840639975	203
6	30	446	145	68	551	509	0.047701691798	0.092178405502	-0.041651125250	0.047701691798	0.046089202751	-0.041651125250	0.175453697550	0.157750533748	203
6	31	414	145	68	547	509	0.042747086277	0.085461344916	-0.038127651577	0.042747086277	0.042730672458	-0.038127651577	0.175441664348	0.157840661426	203
6	32	374	145	68	543	510	0.037733263182	0.078321509826	-0.034440757399	0.037733263182	0.039160754913	-0.034440757399	0.175453237835	0.157877692915	203

Using the Vooya Plug-In Part 4

1. The first pair of columns will be the original reference pattern.
2. Since all plots are normalized into a very large container, secondary pairs could be corresponding color spaces that you'd like to compare (BT.2020 vs BT.709).
3. Additional pairs could be plotted with other conversions that you would like to compare to the original reference pattern
4. Color code each plot and label color keys at the top of the plot

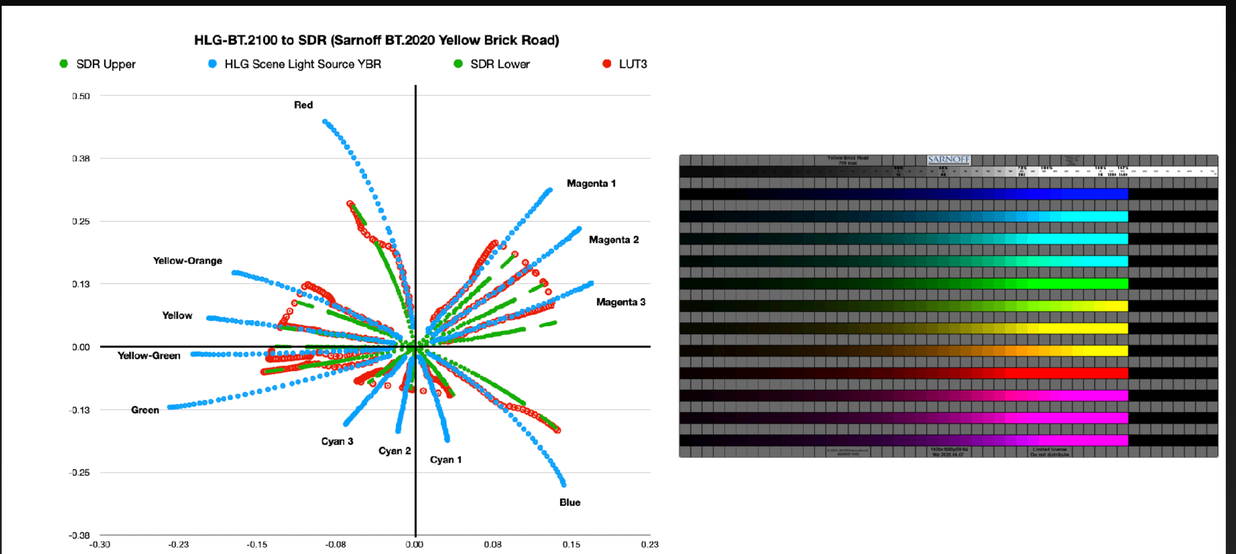
Building Plots Using Apple “Numbers” Part 1

1. Create a new spreadsheet
2. Click on “Chart” tool and select “2D Scatter” (see right)
3. Click “Add Data” under chart
4. Click across data pair in spreadsheet and highlight all the data for the converted values.
5. Repeat this for each conversion pair by adding additional adjacent columns (see next page).
6. Make sure that each conversion pair has a different color.



Building Plots Using Apple “Numbers” Part 1

1. To the right there is an example of a spreadsheet with:
   - the column order
   - The plot
   - A reference picture of the test pattern



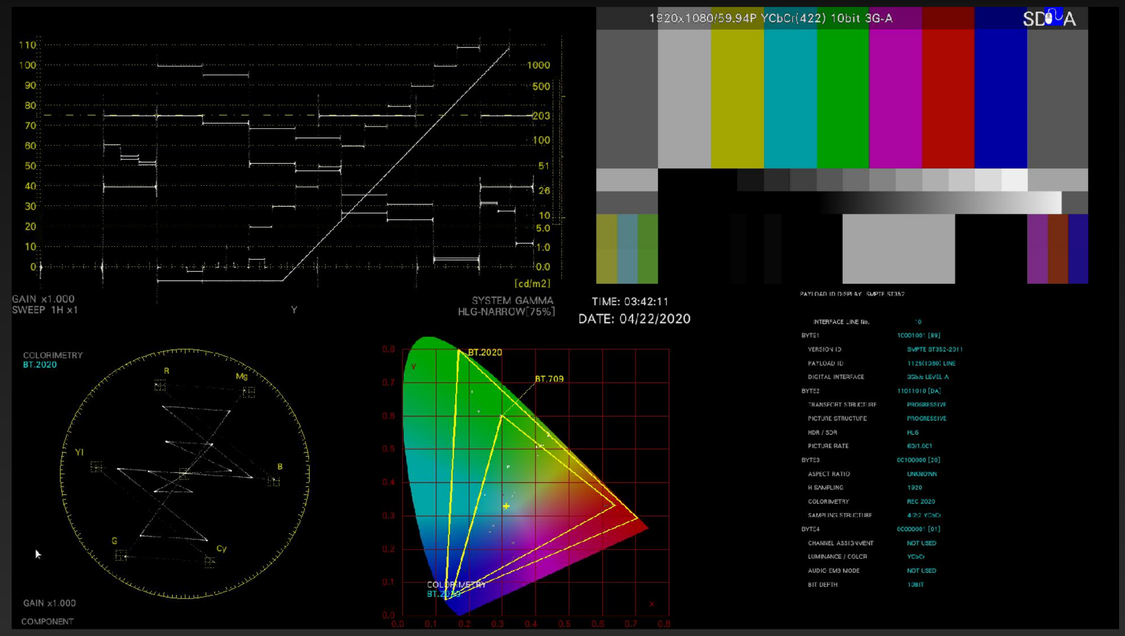
HLG_YBR_Original_Results

Color	WP NITS	ORIGINAL HLG Display Light Constrained to 107%		ORIGINAL HLG Scene Light ITP Source Test Pattern		ORIGINAL SDR UPPER		ORIGINAL SDR LOWER		LUT1		LUT2		LUT3	
		T	P	T	P	T	P	T	P	T	P	T	P	T	P
Blue	1600	0.142015325604	-0.275009645016	0.142799032080	-0.276334418162	0.134868898828	-0.161738502033	0.104883151064	-0.113784048143	0.080790845237	-0.099347584174	0.110139144332	-0.133130710838	0.136691508772	-0.198468200699
Blue	1200	0.142915325604	-0.275999645016	0.141413383650	-0.268334125603	0.134841245659	-0.161373885779	0.103545537812	-0.112169626105	0.080790845237	-0.099347584174	0.110139144332	-0.133130710838	0.136691508772	-0.198468200699
Blue	1000	0.142799032080	-0.275334418162	0.140376634072	-0.263791080262	0.134350763133	-0.160850514304	0.102581221662	-0.110308875160	0.080790845237	-0.099347584174	0.110422185242	-0.133393447098	0.136691508772	-0.198468200699
Blue	800	0.141990489583	-0.271088854226	0.138783615777	-0.257281263254	0.134155010624	-0.160485072255	0.101486997653	-0.109273932947	0.081292369452	-0.099051078293	0.112839720810	-0.135780539654	0.136691508772	-0.198468200699
Blue	630	0.140913911364	-0.266080517468	0.136738895905	-0.249852504814	0.133884262548	-0.159956644751	0.100457993866	-0.107338791871	0.083213905684	-0.098998556828	0.115771130156	-0.138800714073	0.136691508772	-0.198468200699
Blue	500	0.139643100669	-0.260735716231	0.134604860082	-0.242590791647	0.133550936688	-0.159570196544	0.099157766501	-0.106337256571	0.09127*622209	-0.107510662823	0.118978708502	-0.142190372483	0.136691508772	-0.198468200699
Blue	400	0.138182057215	-0.255080715551	0.132244139614	-0.235041966147	0.133349430017	-0.159026186699	0.098188510400	-0.104702355303	0.099008683313	-0.117067774155	0.122177590080	-0.145747864630	0.136691875360	-0.198487142573
Blue	320	0.136638303667	-0.249498765697	0.129679145464	-0.227272917115	0.133097401474	-0.158573219766	0.096796103288	-0.102796503304	0.109217038793	-0.127420061177	0.125597944201	-0.149701904370	0.134906423909	-0.193311117133
Blue	250	0.134718522440	-0.242959623962	0.126578588378	-0.218353879083	0.132815384021	-0.158079452502	0.095756751176	-0.101383167333	0.120771852124	-0.140378606895	0.128090058631	-0.152386450245	0.132396055811	-0.159141337148
Blue	203	0.132917204394	-0.237149220377	0.123676234208	-0.210378539327	0.132553877070	-0.157631254835	0.094261665931	-0.099363296007	0.130728143284	-0.153360281457	0.129039226138	-0.153071598230	0.130122817314	-0.155590208335
Blue	160	0.130664514376	-0.230211971966	0.120217664701	-0.201293078653	0.132228576897	-0.157022868036	0.092987401764	-0.097954531025	0.136035521755	-0.159585526932	0.129392674484	-0.152845393893	0.127414362311	-0.151581036319
Blue	120	0.127634292712	-0.221340356100	0.115603517685	-0.189652736014	0.131999726524	-0.156539746542	0.091534020448	-0.095717585554	0.134676822345	-0.159336125257	0.128298720713	-0.150371307836	0.123844028001	-0.149654605001
Blue	100	0.125724754624	-0.215972320211	0.112696205539	-0.182612793715	0.131551950791	-0.156039645929	0.090159411055	-0.093909919085	0.133911973174	-0.153324840679	0.123841775703	-0.147772319828	0.121670079197	-0.144016141745
Blue	80	0.123084722564	-0.208791800377	0.108728749528	-0.173305745190	0.131403915795	-0.155557306480	0.088411780223	-0.091508904765	0.131699437533	-0.150354254640	0.124285732783	-0.143539678473	0.118584216013	-0.139785859976
Blue	63	0.120217564701	-0.201260378653	0.104550456281	-0.163843001369	0.131053052685	-0.154952544275	0.087101149401	-0.089901168628	0.129423515883	-0.146535011927	0.121267194444	-0.138678184229	0.114814921196	-0.135880290682
Blue	50	0.117219281893	-0.193653947562	0.100182235490	-0.154281400769	0.130759506187	-0.154440142271	0.085205764374	-0.087453271137	0.127166479201	-0.142950650213	0.118209452834	-0.133872017127	0.111215804830	-0.131787180373
Blue	40	0.114145198057	-0.186096571516	0.096035521447	-0.145484712977	0.130430703827	-0.153883315468	0.083581447868	-0.085372881983	0.124718549013	-0.139052648145	0.114982256405	-0.129916110141	0.107416101589	-0.123367086720
Blue	32	0.110963493565	-0.178507910002	0.091817535859	-0.136814573192	0.130125561621	-0.153339536350	0.081717412843	-0.083006129502	0.122027560593	-0.135267359159	0.111767133415	-0.124086547219	0.103386772994	-0.125136633455
Blue	25	0.107405354801	-0.170273668486	0.087018269176	-0.127245339210	0.129745572184	-0.152693723013	0.079943983425	-0.080775186158	0.118320739388	-0.131002423388	0.108123321622	-0.118732412339	0.098948149471	-0.122436718604

What Else is Important to Look At?

1. Check images on the scope by observing absolute levels in waveform and targets in vectorscope.
2. Reference levels to check are available in this document: https://www.itu.int/rec/R-REC-BT.2111-1-201906-I/en
3. Final Checks should include direct visualization via an hdr reference display.
4. Using Y (from XYZ) in absolute NITS and u'v' (absolute chromaticity are also import)
5. Please use the reference equations on the following pages.

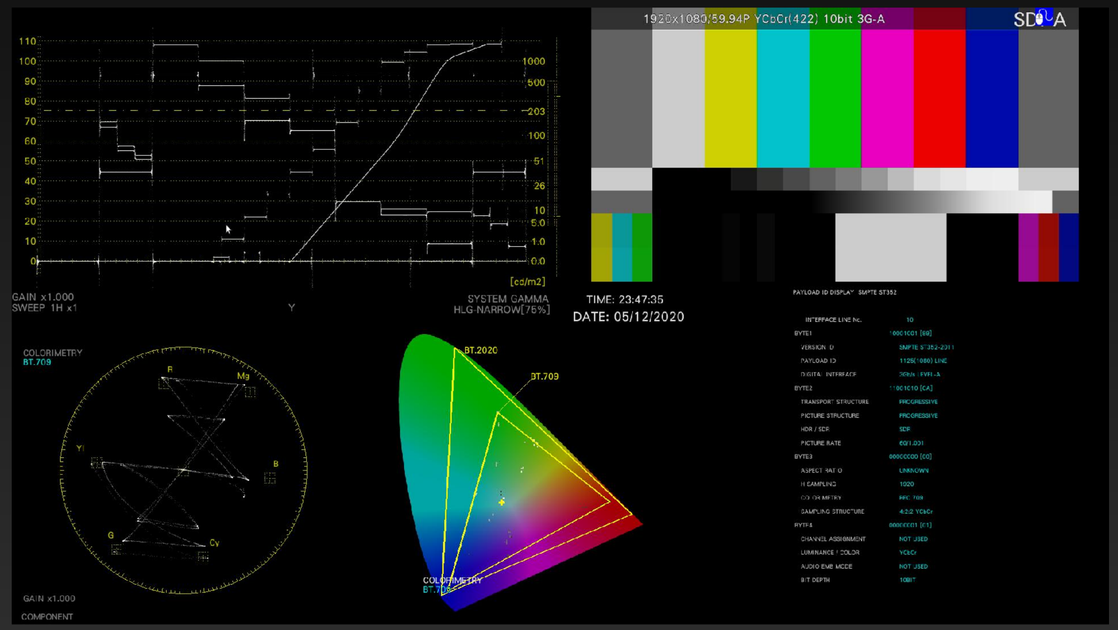
Check Basic Reference Levels



Examples of HDR to SDR Downconversion

1. The scope screenshot to the right is an example of what HDR-to-SDR downconversion might look like with a knee compressing HDR highlights.

HDR-to-SDR Example



Reference Equations

- Reference Spreadsheets for Normalization of YCbCr to ITP, L*u*v*, L*c*h:
  - https://www.dropbox.com/sh/2eju9ctkhrrnt29/AAAG8QIm8FyA3cOrh_hNK1kda?dl=0

- Reference Documents for Normalization of YCbCr to ITP, L*u*v*, L*c*h (these documents are in progress and will be marked “verified” when the formula’s are accurate):
  - https://www.dropbox.com/sh/5uwb2gyu21k52nu/AAAlkpIcxnSgwZvKFsWwIHuVa?dl=0