UHD Single-Master HDR-SDR Production and Transmission

Objective Color Metrics Measurement Using ITU-R BT.2124 Procedures

UHD HDR-SDR Objective Color Metrics Testing

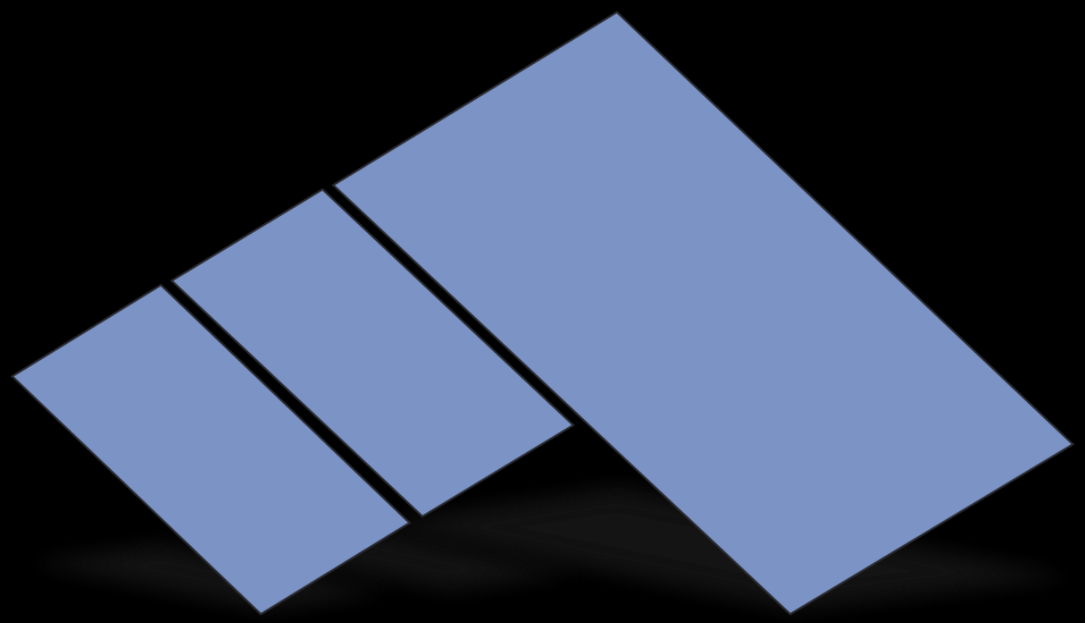
This eBook will evolve as we document the complete workflow.

Lesson Four reviews Objective Color Metrics Testing.

It is provided as a reference for broadcast teams.

Apple Book Store Link is here:
http://books.apple.com/us/book/id6443519839

Lesson 3



HDR/SDR Objective Color Metrics Testing

Making sure your pipeline is accurate

Tools Description

•

List of Tools and Patterns

•

How to gather test data

•

Plotting

The purpose of Objective Color Metric Measurement?

Many current image measurement metrics are tailored around measuring luma difference but not color volume accuracy.

Additionally, many current metrics are not specifically designed for HDR and SDR.

These sets of tools convert all signal formats into a single color-representation known as ITP where “I” is intensity and T/P represent color using a perceptual model and constant hue. The ability to see hue divergency is improved.

The color volume difference metric we use is documented in Recommendation ITU-R BT.2124

Software and Test Patterns Required

Software

- Vooya Video Player ($29.99)
  - Vooya Chroma Grapher - Measures values and converts them to ITP, y'u'v, nits ($70/6month)
- Apple Numbers Spreadsheet
  - Click to download reference plotting spreadsheets

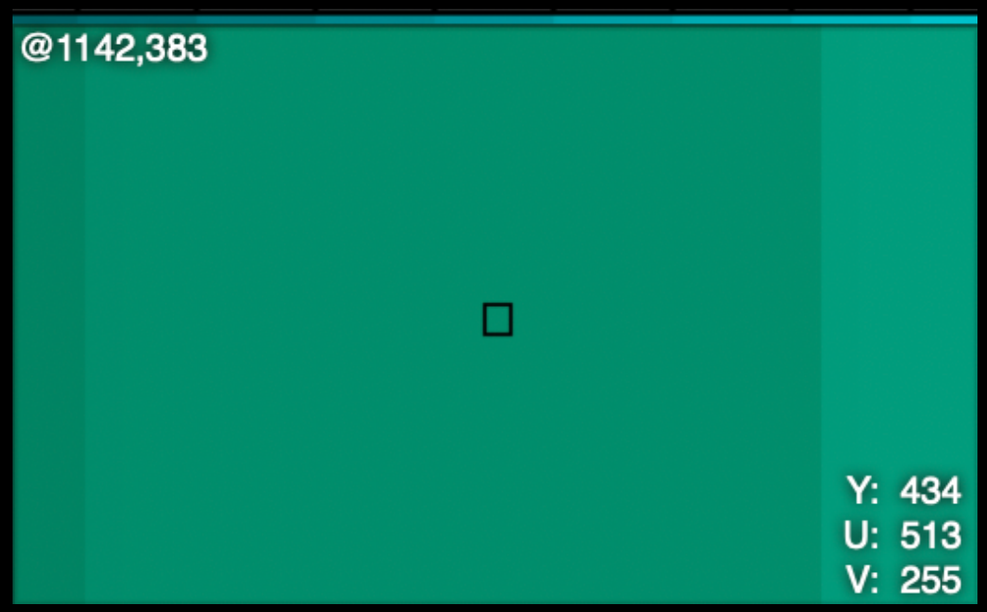
Test Patterns

- BT.2111 Fancy Bars - Evaluate basic levels using conventional vector scope and waveform
- Sarnoff Test Pattern: Yellow Brick Road
  - HLG BT.2100 Scene-Referred
  - PQ BT.2100
  - SDR BT.709 Condensed 2m-123IRE

Applications Required for Plotting

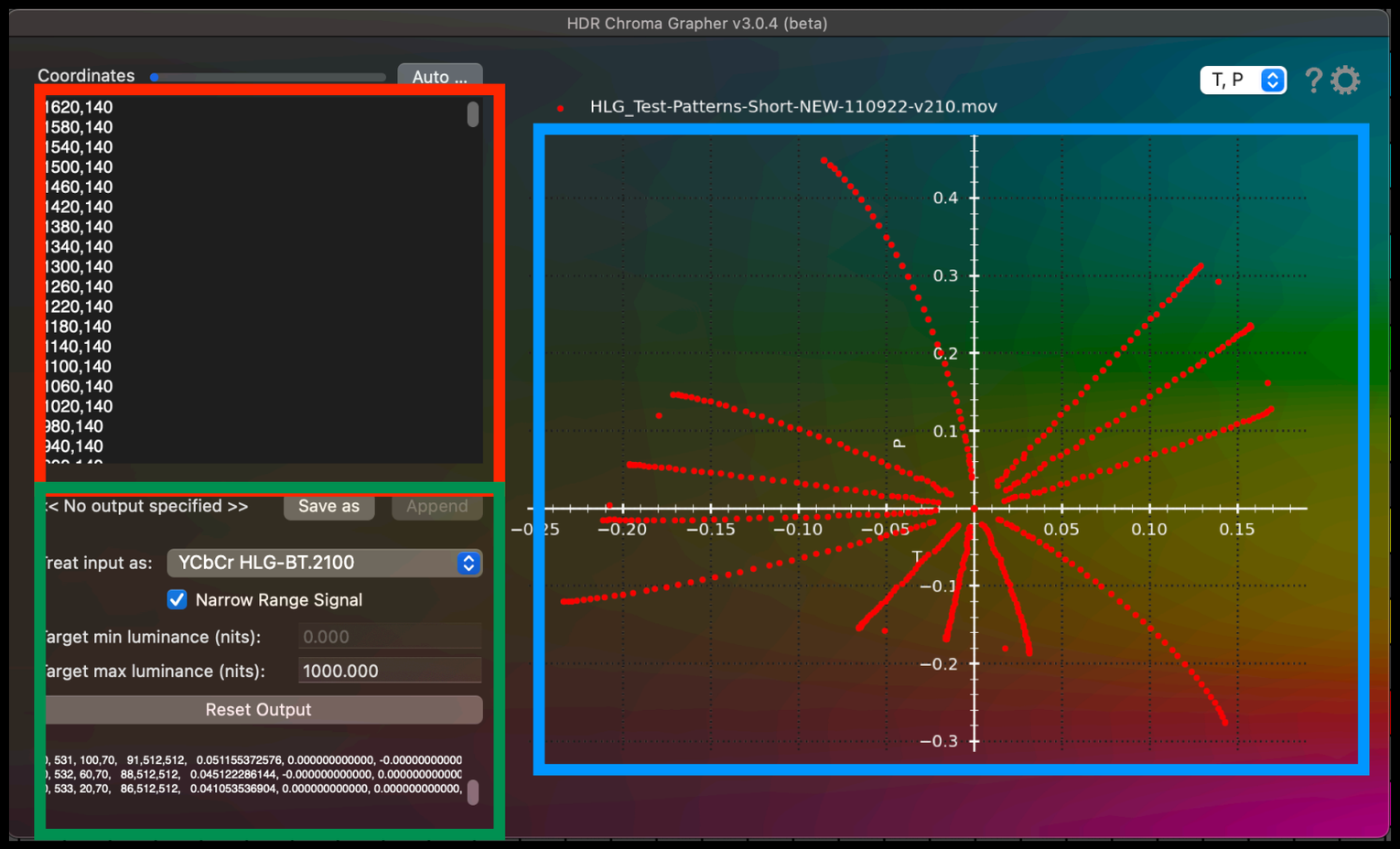
- **Basic T/P Plotting within Vooya**
  - **Vooya Video Player: Install in “Applications Folder”**
    - **Chroma Metric Plug-in: Install in Vooya Plug-Ins folder (typically in users home folder)**
    - **Simple T/P plotting internal to Vooya only works if Python and dependencies are installed (See Annex)**
- **Sophisticated Plotting Outside of Vooya**
  - **Apple Numbers templates have been built and allow very sophisticated plotting by copy/pasting results from Vooya into a spreadsheet**
  - **Click here for spreadsheet templates**

Build list of locations to test using Vooya



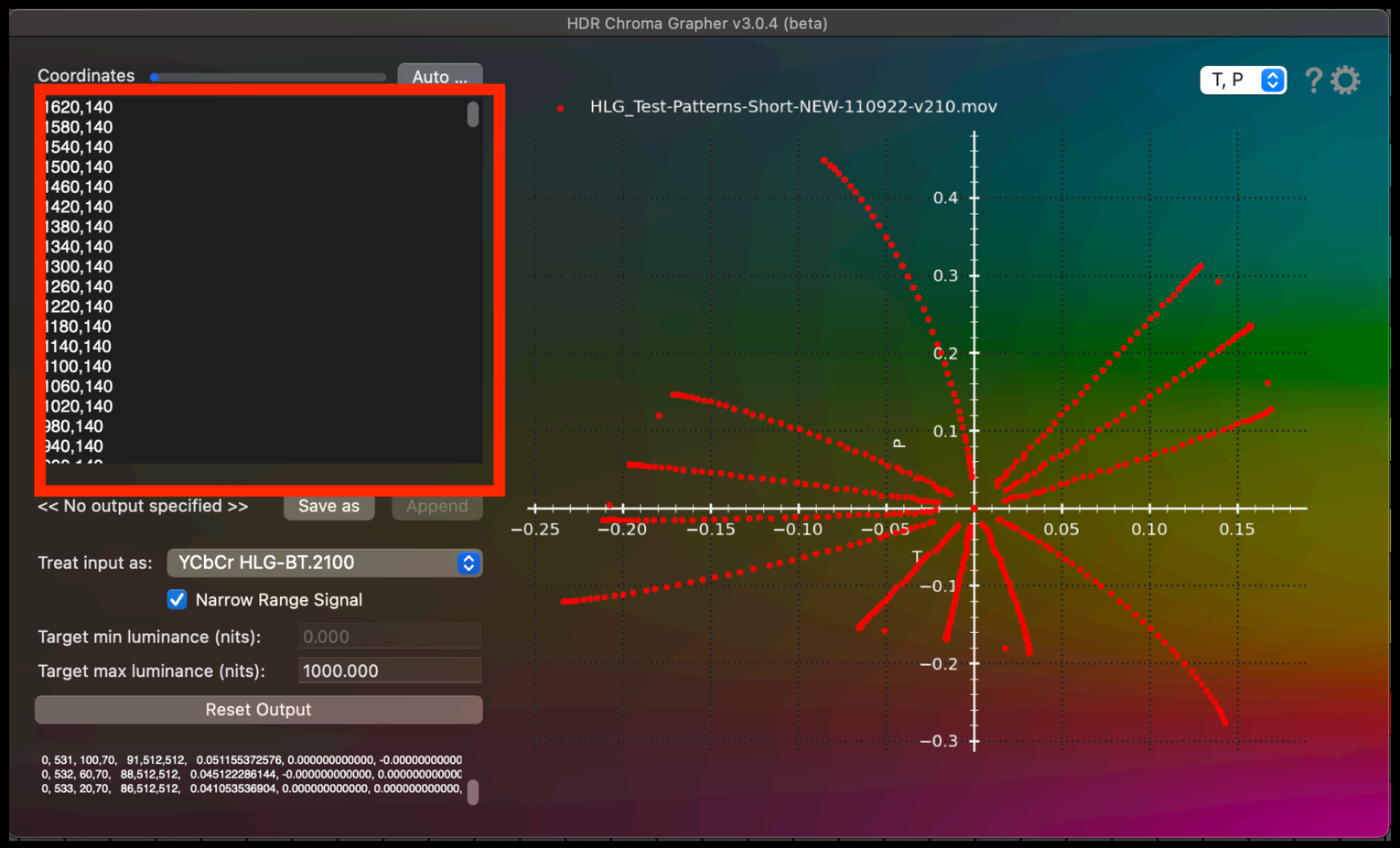
1. Open movie in Vooya
   - Enable “Magnifier” tool
   - Drag “Magnifier” over image to gather pixel locations that are to be tested and save all coordinates to a comma-delimited text file.
2. Each x,y pixel location should be on a separate line (use a carriage return between each entry).
3. Store CSV text files for future use. Full value list will be copy/pasted into Vooya Chroma Metric plugin window.
   - A pre-built list of coordinates files have been created for Sarnoff Yellow Brick Road patterns and can be downloaded from the Github Repository.

Introduction: Chroma Metric Vooya Plug-In



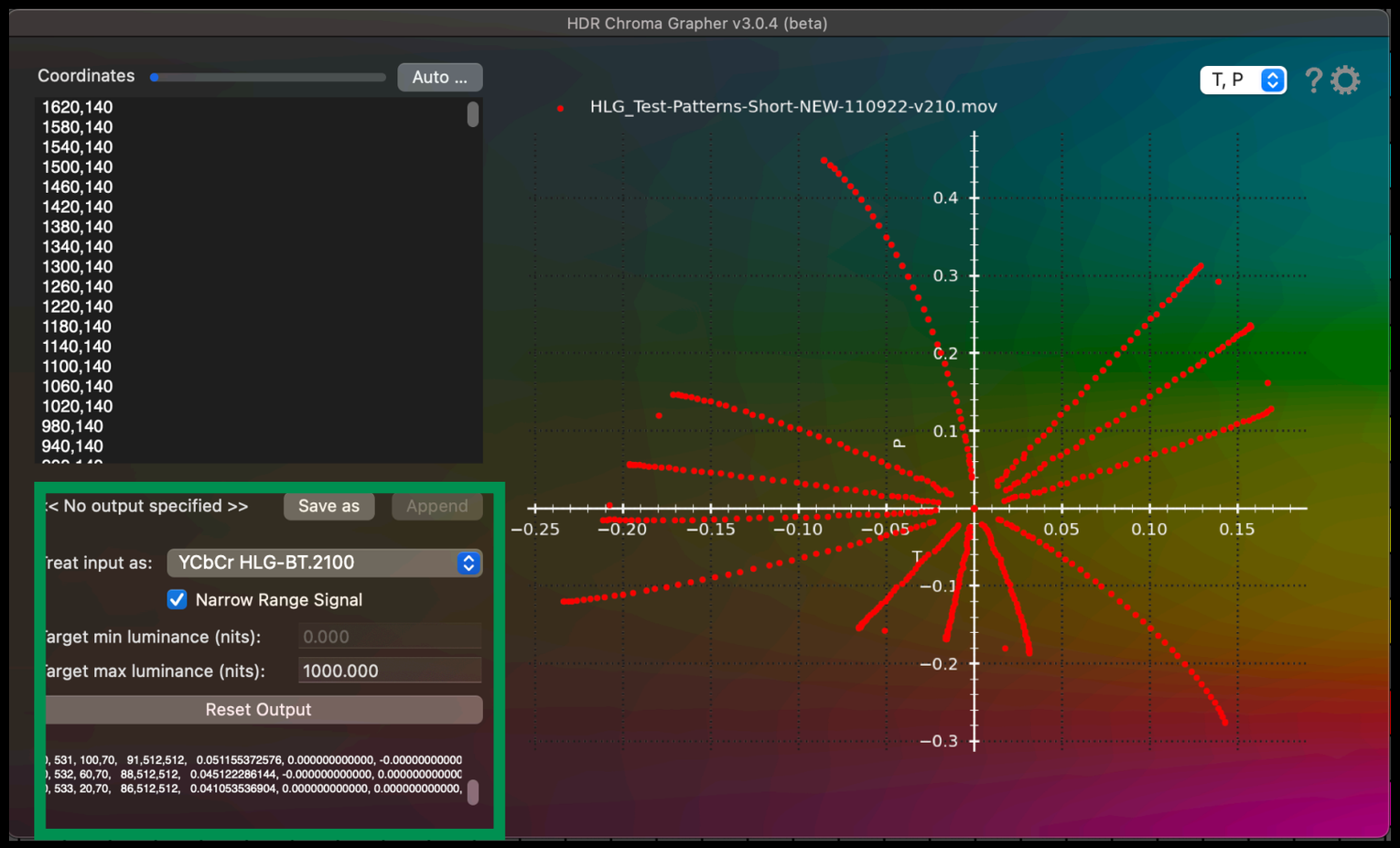
1. **Red Box = CSV pixel locations to measure Y'CbCr values from video image.**
2. **Green Box = Set signal format, peak luminance, signal range**
3. **Blue Box = T/P (from ITP) color plot for checking hue diversions**
    - **Requires the installation of Python and dependencies**

Using Chroma Metric Vooya Plug-In



1. Paste x,y test locations list from a text file into upper left field (red box).
   - Our Github repository has a set of coordinates for several patterns.
2. Click “Reset Output” then immediately follow with Step 3
3. Set video format (using “Treat Input As”), signal range and max luminance level for SDR (HLG and PQ have default values). We use an SDR peak-white of 203nits (this matches consumer displays more closely and aligns with HDR reference white).
4. Click “Save As” button to save the results to a CSV file which will be pasted into the plotting spreadsheet.

Introduction: Chroma Metric Vooya Plug-In



1. “Reset Output”: Resets conversion before selecting input format
2. “Treat Input As”: Chose SDR Gamma 2.4, HLG or PQ
3. Enable on “Narrow Range” selector for broadcast video.
4. Set Min/Max Luminance in nits or cd/m²:
    1. SDR: 0 cd/m² for min, 203 cd/m² for max
    2. HLG: Defaults to 1,000nits (Normalized value established in Recommendation ITU-R BT.2408)
    3. PQ: Defaults to 10,000nits
5. “Save As”: Saves Comma-Delimited text file for import to plotting spreadsheet

Introduction: Chroma Metric Vooya Plug-In

- **T/P Basic Color ONLY Plotting (BLUE Box) will occur if all coordinates are entered**
- **This plotting capability allows multiple movies to be compared (as seen above).**
- **Clicking the gear icon (upper right), allows several parameters including plotting color to be changed**
- **The plot above compares BT.2020 vs BT.709 color spaces**

Plotting Spreadsheets, Mathematics Reference

- Reference files For "Objective Color Metrics" on Github are here:
  - Click here for reference spreadsheet templates, test pattern coordinates and other documentation.

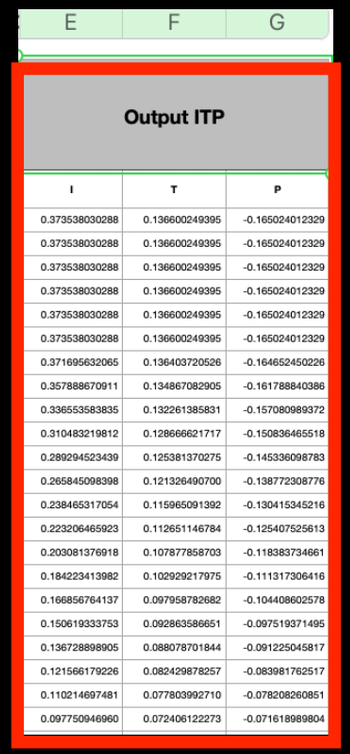
Example: CSV Output from Vooya

HLG BT.2100 Scene-Light Pattern - Sarnoff Yellow Brick Road

Frame	Pixel Nr.	x	y	Y	Cb	Cr	I	Ct	Cp	I	T	P	Y'	u'	v'	nits	min_nits	max_nits	Input
0	1	1620	140	121	1001	473	0.496036461322	0.285921069999	-0.276259031884	0.496036461322	0.142960534999	-0.276259031884	0.460475387940	0.159270583581	0.125835935232	61.71	0.000	1000	YCbCr HLG-BT.2100
0	2	1580	140	120	998	473	0.491154330809	0.285598064161	-0.275334418162	0.491154330809	0.142799032080	-0.275334418162	0.455722775054	0.159270516717	0.125835866261	58.75	0.000	1000	YCbCr HLG-BT.2100
0	3	1540	140	118	975	475	0.458531925402	0.282953479501	-0.268627899188	0.458531925402	0.141476739750	-0.268627899188	0.424034202767	0.159270581284	0.125835942689	42.09	0.000	1000	YCbCr HLG-BT.2100
0	4	1500	140	116	960	476	0.437330863440	0.280753268145	-0.263761080262	0.437330863440	0.140376634072	-0.263761080262	0.403505987136	0.159270518525	0.125835868201	33.72	0.000	1000	YCbCr HLG-BT.2100
0	5	1460	140	114	942	477	0.412842994857	0.277700250614	-0.257613861542	0.412842994857	0.138850125307	-0.257613861542	0.379863191635	0.159270499474	0.125835942954	25.95	0.000	1000	YCbCr HLG-BT.2100
0	6	1420	140	112	922	479	0.386698437937	0.273785920296	-0.250396549950	0.386698437937	0.136892960148	-0.250396549950	0.354705055216	0.159270533509	0.125836079397	19.47	0.000	1000	YCbCr HLG-BT.2100
0	7	1380	140	109	902	481	0.360951540589	0.269209720164	-0.242590791847	0.360951540589	0.134604860082	-0.242590791847	0.330019052673	0.159270552262	0.125835901210	14.54	0.000	1000	YCbCr HLG-BT.2100
0	8	1340	140	107	884	482	0.339200169149	0.264733403863	-0.235423554620	0.339200169149	0.132366701932	-0.235423554620	0.309237094599	0.159270516717	0.125835866261	11.27	0.000	1000	YCbCr HLG-BT.2100
0	9	1300	140	105	864	484	0.316294622197	0.259358290927	-0.227272917115	0.316294622197	0.129679145464	-0.227272917115	0.287428926186	0.159270750826	0.125836096447	8.54	0.000	1000	YCbCr HLG-BT.2100
0	10	1260	140	102	843	485	0.293104235017	0.253157176756	-0.218353879083	0.293104235017	0.126578588378	-0.218353879083	0.265434150565	0.159270516717	0.125835866261	6.38	0.000	1000	YCbCr HLG-BT.2100
0	11	1220	140	100	824	487	0.273792691029	0.247352468417	-0.210378539327	0.273792691029	0.123676234208	-0.210378539327	0.247187171003	0.159270516717	0.125835866261	4.95	0.000	1000	YCbCr HLG-BT.2100
0	12	1180	140	98	802	489	0.253144198990	0.240435329403	-0.201260378653	0.253144198990	0.120217664701	-0.201260378653	0.227750667194	0.159271318640	0.125836776658	3.74	0.000	1000	YCbCr HLG-BT.2100
0	13	1140	140	94	774	491	0.228748700513	0.231207035169	-0.189652736914	0.228748700513	0.115603517585	-0.189652736914	0.204891736621	0.159270516717	0.125835866261	2.63	0.000	1000	YCbCr HLG-BT.2100

1. Above are a few rows output from a single Vooya test of the Sarnoff Yellow brick road pattern (1,014 sampled values).
2. To plot the sampled values, every row of ITP values must be copied into the operating systems clipboard (Command-C after highlighting the ITP columns and rows)
3. The ITP values get pasted into the spreadsheet template based on what formats you are trying to compare.
4. There are different spreadsheets for HLG vs SDR; SDR vs HLG, HLG vs PQ
5. There are different spreadsheets targeted for specific comparisons. Some examples include: HLG vs SDR; SDR vs HLG, HLG vs PQ

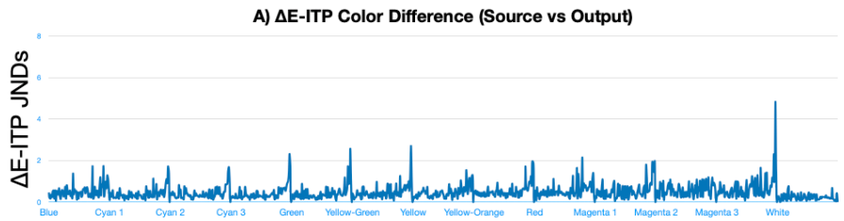
Example: Pasting results into plotting spreadsheet

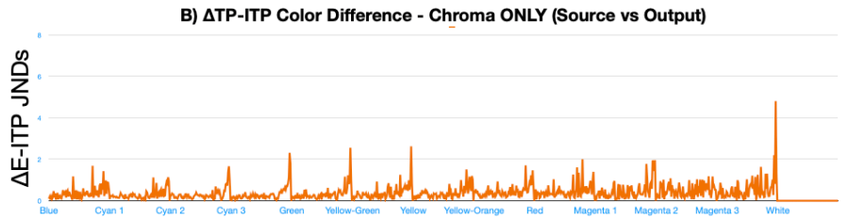


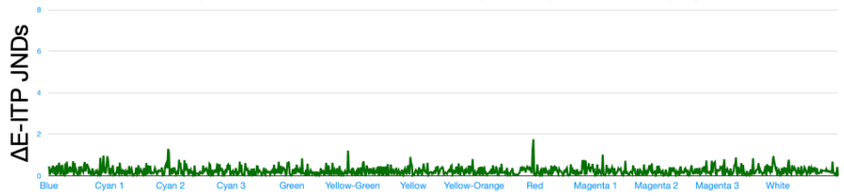
E	F	G
	Output ITP	
I	T	P
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.373538030288	0.136600249395	-0.165024012329
0.371695632065	0.136403720526	-0.164652450226
0.357888670911	0.134867082905	-0.161788840386
0.336553583835	0.132261385831	-0.157080989372
0.310483219812	0.128666621717	-0.150836465518
0.289294523439	0.125381370275	-0.145336098783
0.265845098398	0.121326490700	-0.138772308776
0.238465317054	0.115965091392	-0.130415345216
0.223206465923	0.112651146784	-0.125407525613
0.203081376918	0.107877858703	-0.118383734661
0.184223413982	0.102929217975	-0.111317306416
0.166856764137	0.097958782682	-0.104408602578
0.150619333753	0.092863586651	-0.097519371495
0.136728898905	0.088078701844	-0.091225045817
0.121566179226	0.082429878257	-0.083981762517
0.110214697481	0.077803992710	-0.078208260851
0.097750946960	0.072406122273	-0.071618989804

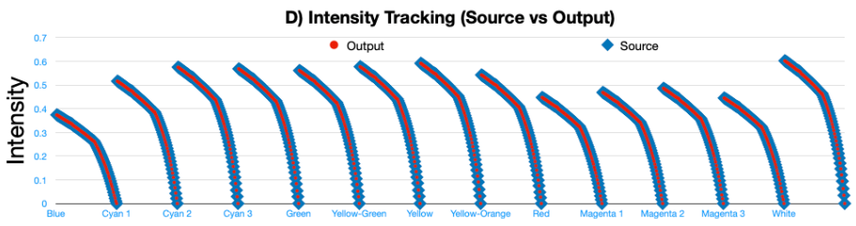
1. **ITP values previously copied into the clipboard, get pasted into the “Output ITP” columns.**
2. **The spreadsheet templates contain reference measurements for comparison to the new results pasted into them.**
3. **If you need to test other patterns, new coordinates, reference values need to be gathered and constructed into a new spreadsheet template.**

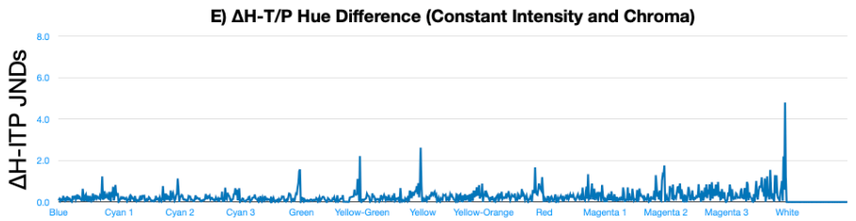
Example: Pasting results into plotting spreadsheet

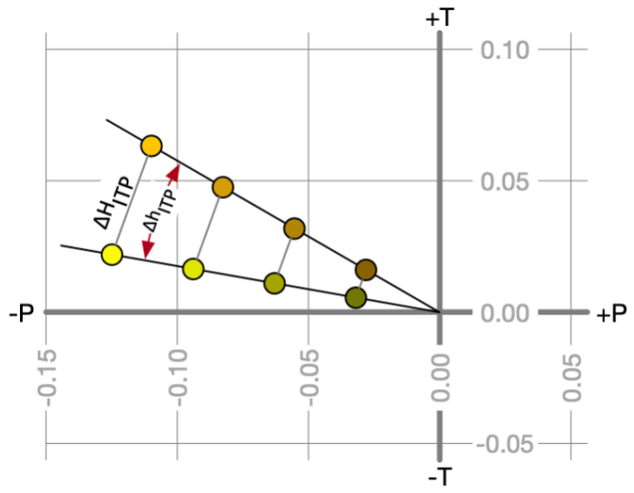




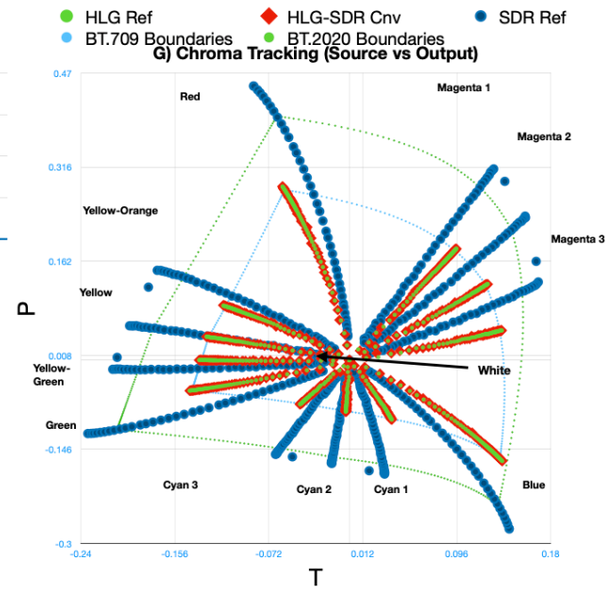


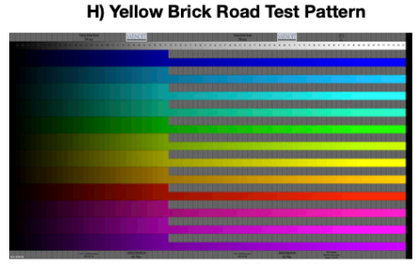






The samples in each color difference pair have the same chroma, for being the same distance from the origin. The hue angle difference Δh_{ITP}, in this illustration from yellow to yellow-orange, is constant for these pairs, but the hue difference ΔH_{ITP} increases proportionally to a pair's chroma.





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1. The spreadsheet template above compares 3 different video formats without conversion in one plot (HLG vs PQ vs SDR-Passthrough in an ITP container).
2. It shows subtle error in the ΔE-ITP plot. ΔE-ITP shows a JND(Just-Noticable-Difference) for any value above 1.
3. Learning how to read these plots and interpret them takes a little experience.

UHD HDR-SDR Objective Color Metrics Testing

ANNEX 1

Installing Python and Dependencies in MacOS

1. Install Python 3.10 from python.org
    - Run Python3 "Install Certificate" installer
    - Run Python3 "Update Shell Profile installer"
2. Upgrade PIP and install necessary modules from “Terminal"
    - pip3 install --upgrade pip
    - pip3 install matplotlib
    - pip3 install dumpy
3. Add the following to ~/.zprofile:

```
alias python=‘python3’

# Set explicit path to Python for Vooya
export # Vooya Python path control
export HDR_CG_PYLIB=/Library/Frameworks/Python.framework/Python

# Setting PATH to current Python version
PATH="/Library/Frameworks/Python.framework/Versions/Current/bin:${PATH}"
export PATH
```