2018 Value Electronics TV Shootout

Out of the Box vs. Professional Calibration and the Comparison of DeltaE 2000 & Delta ICtCp

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Presentation Goals

➢ Define calibration and its benefits
➢ How do we measure calibration accuracy?
➢ What is color difference and how is it measured?
➢ DeltaE 2000 vs Delta ICIcP
➢ Typical out of the box calibration scans
➢ Comparisons of DeltaE 2000 and Delta ICIcP measurements
➢ Typical improvements with proper calibration
What is Calibration?

Calibration is matching a device to a standard

- White Point
  - D65 x = .313 y = .329 or Custom White Point

- Gamma
  - 2.2, 2.4, BT1886 for SDR
  - Light output curve based on CRT physics

- Electro Optical Transfer Function (EOTF) HDR & Dolby Vision
  - SMPTE ST2084 defines the process by which digital code words are converted into visible light

- Color
  - Rec.709, DCI/P3, REC.2020
What are the Benefits of Calibration?

➢ Achieving the most accurate viewing experience so that all colors are the same across all platforms from content creation, to production, to consumer displays
  ▪ Full picture details in the darkest and brightest parts of all scenes
  ▪ Eliminating or minimizing Crushing of Blacks and Clipping of Whites and picture Artifacts (Distortions)
  ▪ Accurate production of the full range of colors without exaggeration
How Do We Measure Calibration Accuracy?

➢ Perceptual Color Difference Metrics
   ▪ Predict color differences as closely as possible to the way humans see them.

➢ Just Noticeable Difference
   ▪ Threshold where humans can perceive a difference between two colors and where two colors appear identical.
Color Difference

➢ Measure of change in visual perception of two given colors
   ▪ How the human eye perceives the difference between two colors

➢ Color Difference Metrics
   ▪ DeltaE 2000 (CIE)
   ▪ Delta ICtCp (created by Dolby Labs)
   ▪ Designed to match how humans see color
   ▪ Based on mathematical formulas to compensate for the human eye’s sensitivity to some areas of color and less sensitivity to others
   ▪ Has to be repeatable and user independent
DeltaE 2000 vs. Delta ICtCp

➢ DeltaE 2000
  ▪ Commonly used Industry Standard
  ▪ Formula assumes the human visual system is adapted to white, so you see smaller errors and more inaccurate measurements near black
  ▪ Inaccuracies with HDR and WCG displays because data set does not cover this expanded color range.
DeltaE 2000 vs. Delta ICtCp, continued

➢ Delta ICtCp
  - Formula assumes unlimited adaption states so the human visual system is adapted to each color for the patch you are measuring
  - Predicts gamma and grayscale errors more accurately at the low end (closest to black) and at the high end (closest to white)
  - Designed for HDR and WCG displays
  - Works for SDR displays as well
Calibration Accuracy Considerations

➢ It is important to consider how well a metric adheres to human vision across a wide range of colors and luminance levels

➢ Some metrics perform accurately for certain colors and poorly for others

➢ Depending on the metric used, calibrated displays could appear not to match visually even though their color difference values agree
  ▪ DeltaE 2000 may significantly over or under predict color differences
  ▪ One display’s blue may trend toward red and another display’s toward green making the sets look perceptually different
ICtCp vs. Delta ICtCp

➢ ICtCp is an encoding space similar to YCbCr
➢ Delta ICtCp is a Color Difference Metric
ICtCp New Color Encoding Model - Reference

ICtCp

- A color representation model designed for HDR and WCG displays which challenges existing image and video data processing algorithms such as YCbCr in terms of compression and accuracy
  - New non-linear encoding curves, EOTF
  - New color primaries, more saturated colors
  - Increased bit depth
ICtCp New Color Encoding Model - Reference

ICtCp, continued

More perceptually uniform color representation that is based on the human visual system by decorrelating Saturation, Hue and Intensity

- I - Intensity: Black/White intensity
- Ct- Tritan: Blue-Yellow axis of human vision
- Cp- Protan: Red-Green axis of human vision

Ct/Cp in ICtCp like Cb/CR in EOTF encoded Y’C’bC’r are the color difference channels

Defined from Rec. 2100

Proposed for ATSC 3.0; Used by Netflix DV content
ICtCp vs. YCbCr - Reference

ICtCP can replace YCbCr

- Improved chroma subsampling and gamut mapping
- Less distortions than YCbCr for HDR and WCG; less color “leakage” into luminance channel
- Better overall image quality and perceptual uniformity
- Better compression requires lower bit rates
Pre-Calibration View
Out of the Box Expert PM
Gamma 2.4, D65

Avg Gamma: 2.36
- Pretty Close to 2.4

Avg dE2000: 1.16
- Perceptual Errors OK < 3.0

Avg CCT: 6551
- Avg White Point OK

RGB Balance
- Pretty good Balance
- But Blue Push

Gamma Log/Log
- Black Crush
- Incorrect Gamma

DeltaE 2000
- Incorrect Delta H
- Oversaturated
- White Point Towards Blue
- Undersaturated

CIE 1931 xy
- Incorrect Delta H
- Oversaturated
- White Point Towards Blue
- Undersaturated
Pre-Calibration View

Avg Gamma: 2.36
Avg dE2000: 1.16
Avg CCT: 6551
Pre-Calibration View

Avg Gamma: 2.36
Avg dE2000: 1.16  Avg dE ICtCp: 1.4
Avg CCT: 6551

Delta ICtCp Shows Perceptible Error
Calibrated Expert PM
Gamma 2.4, D65
Corrected Gamma
Good ΔE2000 < 0.5
Corrected Balance
White Point
Corrected
Better But Not Perfect CMS

Avg Gamma: 2.4
Avg dE2000: 0.12
Avg ΔE IctCp: 0.14
Avg CCT: 6505
Good Avg White Point

Corrected Gamma
Good ΔE2000 < 0.5
Perceptual Errors Improved
Post-Calibration View
Calibrated Expert PM
Gamma 2.4, D65

- Avg Gamma: 2.4
- Avg dE2000: 0.12
- Avg dE ICC: 0.14
- Avg CCT: 6505
- Good Avg White Point

Corrected Gamma
Corrected Balance
White Point Corrected
Better But Not Perfect CMS

Perceptual Errors Improved
Adjust Multipoint Grayscale & Gamma

Use the charts below to adjust both the best color balance and the target luminance level for each point along the luminance response to obtain a DeltaE of less than 3.*

Average DeltaE: 0.11  Average Gamma: 2.4

Avg CCT: 6520.9  Max Nits: 268.71  Max fL: 78.43
Adjust Multipoint Grayscale & Gamma

Use the charts below to adjust both the best color balance and the target luminance level for each point along the luminance response to obtain a DeltaE of less than 3.*

Average DE ICTCp: 0.18  Average Gamma: 2.4

Avg CCT: 6520.9  Max Nits: 268.71  Max fL: 78.43
ColorChecker

DeltaE 2000

Avg dE2000: 0.9
Max dE2000: 1.7

Current Reading
x: 0.3123
y: 0.3292
fl: 78.77
cd/m²: 269.9

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Target x:CIE31 0.3127
Target y:CIE32 0.3290
Target y:CIE33 269.8986
Target y:CIE34 249.4580
Target y:CIE35 237.2862

ΔE 2000: 0.5081

RGB Triplet: 235, 235, 235
Grayscale

Avg dE2000: 3.16
Max dE2000: 9.5
Color Temperature Avg: 6504
Max White Level Nits: 10000
Black Level Nits: 0

Current Reading
x: 0.3135
y: 0.3337
fL: 1.36
cd/m²: 4.68
References

   ▪ Jaclyn A. Pytlarz, Elizabeth G. Pieri
   ▪ Dolby Laboratories Inc., USA

2. ICtCp White Paper
   ▪ Dolby Laboratories

3. Dolby Demonstrates ICtCp Color Model at SMPTE 2017
   ▪ Scott Wilkinson, AVS, October 31, 2017

4. Hitting the Mark - A New Color Difference Metric
   ▪ Jaclyn Pytlarz, SMPTE 2017