Victor Steinberg

Video Standards

Signals, Formats and Interfaces

Part 3

Illuminant, Color Temperature, Color Balance

www.videoq.com

Real World Colors

All objects present in video images captured by a video camera can be split into three major categories:

- **Light emitting objects** – e.g. sky, sun, traffic lights, fluorescent paints
- **Light transmitting objects** – e.g. colored glass window, 35 mm film
- **Light reflecting objects** – nearly all real world objects: landscapes, animals, human faces, etc.

Sky is a light emitting object

Cloud, in this example, is a semi-transparent object.
Thus, it is a light transmitting and light reflecting object

Sea surface is a light reflecting object

Light flux captured by a video camera

In terms of CIE 1931 model the XYZ (and RGB) color values of the reflective and transmissive cases are similar to the emissive case (*see Part 2*), but with one very important difference:
The **spectral radiance L(λ)** of the light emitting object is replaced by the **spectral reflectance** (*or spectral transmittance*) **S(λ)** of the object being measured, multiplied by the spectral power distribution of the **illuminant I(λ)**.
Thus, for the objects of two last categories there is no point to talk about their colors **without the full specification of the illuminant**.
Change of illuminant usually means change of **objectively measured color** – as simple as that!

$$X = \frac{K}{N}\int_{\lambda} S(\lambda)\, I(\lambda)\, \bar{x}(\lambda)\, d\lambda,$$
$$Y = \frac{K}{N}\int_{\lambda} S(\lambda)\, I(\lambda)\, \bar{y}(\lambda)\, d\lambda,$$
$$Z = \frac{K}{N}\int_{\lambda} S(\lambda)\, I(\lambda)\, \bar{z}(\lambda)\, d\lambda,$$
$$N = \int_{\lambda} I(\lambda)\, \bar{y}(\lambda)\, d\lambda$$

N = normalization factor (illuminant luminous energy),
K = scaling factor, usually 1 or 100.

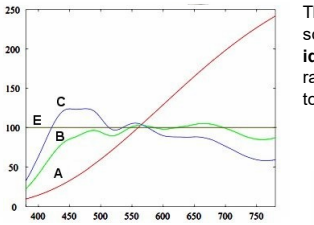
Illuminants & Color Temperatures

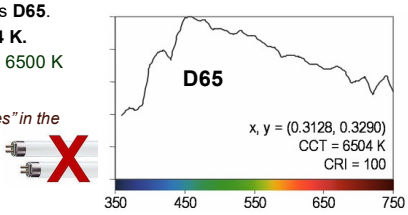
A **standard illuminant** is a ***theoretical*** source of visible light with a specified **Spectral Power Distribution (SPD).**
The CIE standard illuminants provide a basis for comparing images/colors recorded/viewed under different lighting.
They are traditionally designated by a letter or by a letter-number combination:

- **A** = "Old-fashioned" incandescent (tungsten filament) lighting, with a **Correlated Color Temperature (CCT)** of **2856 K**
- **B** = noon (direct) sunlight, with a **CCT** of **4874 K**
- **C** = average day light (light in the shade) with a **CCT** of **6774 K**.
  Once more realistic simulations were achievable, Illuminants B & C were deprecated in favor of currently used ***D series***
- **E** *is a theoretical reference equal-energy radiator with equal weight to all wavelengths inside the visible spectrum. It has equal CIE XYZ tristimulus values, thus its chromaticity coordinates are (x,y) = (1/3,1/3).*
- **D** = daylight series, 4000 K ~ 14000 K, the most important is **D65**.
  D65 = average midday light (cloudy sky) with a **CCT** of **6504 K.**
  Only the light sources with color temperatures ≈ 5000 K … 6500 K can be recommended for the **outdoor video production**.

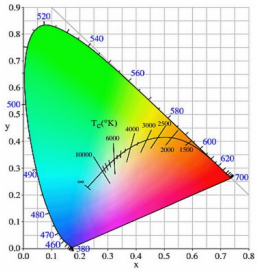
  Note that "old-style" fluorescent light sources with "mercury spikes" in the SPD may cause noticeable color distortions.

BTW: So called "warm colors" (yellowish white through red) actually has a "cooler" (lower) ***color temperature*** *values. This often leads to confusion.*





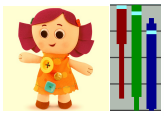
The **color temperature** of a light source is the temperature of an **ideal black-body radiator** that radiates light of a color ***comparable*** to that of the light source.



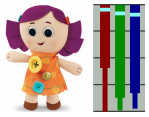
Correlated **C**olor **T**emperature

Color Temperature & Color Balance

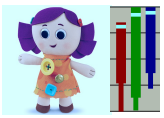
Color Temperature (K)	Light Source
1,500	Candle
3,200	Sunrise and sunset
3,400	Tungsten lamp
5,500	**Natural daylight**
6,000	**Overcast sky**
8,000	Shade on a sunny day
12,000	Blue sky



If you select the "**Daylight**" mode for your video camera instead of the default "**AUTO**" mode, then …



Without auto-balance controls only **one** of three captured images will exhibit good color balance.



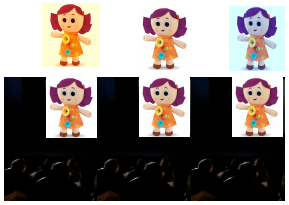
Our eyes (in fact – brains) have a wonderful ability to **auto-correct white balance errors**, but only in the darkness of home theatre or movie theatre, where we are not seeing at the same time any **undistorted familiar objects** (reference colors).

Whilst watching TV in a relatively well lit living room full of familiar objects, such as wallpaper, furniture, etc., this wonderful ability vanishes.

Captured images:

HOME THEATRE

Perceived images:



All three images exhibit good color balance

Captured images:

LIVING ROOM

Perceived images:

Only one image exhibits good color balance

About Color Balance

Creative Guy

Color balance is quite useful feature of video images.

It helps me to create a “mood”, an artistic impression, and …

… to implement all my wonderful creative ideas, and to deliver my message to the world.

And it may help me to get all these long awaited and well deserved **International Awards !**

Yea…, but color balance is much more than just a feature of video images.

For me it is mainly a feature of long and sophisticated **signal processing chain**: from the camera lens to the display screen.

If we allow video processing parameters to deviate from the balanced target values, the output images will be not so good.

Then the whole project will be closed, and **I will lose my job !**

Video Engineer

It’s a team work, so let’s care about the color balance together.

Color Balance – Comments & Components

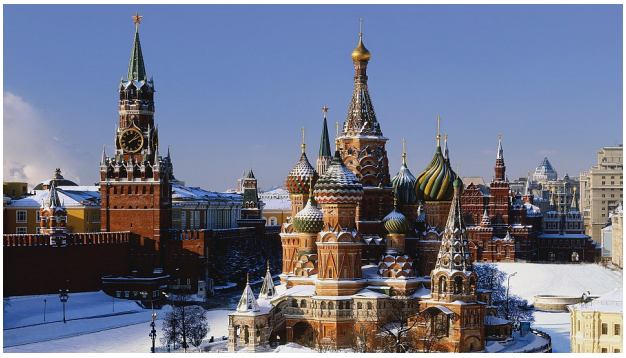
Good picture, professional job.

I like the bluish tint of shadows on the snow and deep blue sky as a hint of cold winter.
My colorist can tweak ***any*** image in **post production**, so I don’t care.

I don’t see any chances to use this image.

Maybe for the documentaries it’s OK, but for me it is just **boring**!

I have better plans for this evening, so bye for now …



Good picture, professional job.

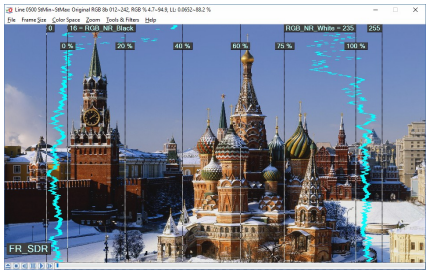
I see small offset of **White Balance** and good **Black Balance**.
Not sure about **Gray Balance**.

Good **Chroma Saturation**, no **Black Crush** or **White Crush**.

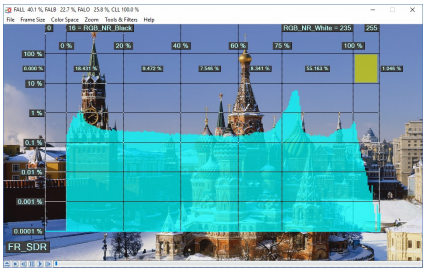
Good **RGB Dynamic Range**, and **RGB Median Levels** look OK.

But, to be sure, I have to check this file with my QA/QC tools.

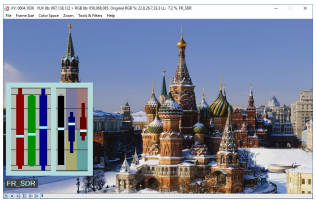
What VideoQ VQV Analyzer Reveals About Color Balance



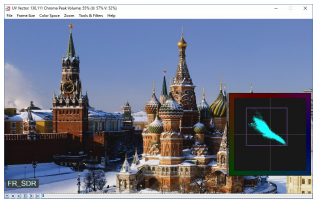
Good **RGB Range** for nearly all frame lines



Uniform **Light Levels Histogram**, 1% **White Crush** (Yellow Overload Marker)



Frame Statistics: nearly full **RGB Range**, and quite strong offset of **RGB** & **UV Median Levels** (Blue color domination)



UV Vectorscope reports 55% **Chroma Peak Volume** and distinct presence of 40% saturated Red, Brown and 20% saturated Blue colors

About This Presentation

Produced by	**Josef Marc**
Written by	**Victor Steinberg, PhD**
Narrated by	**Josef Marc**
Conceived by	**Roderick Snell**
Technical consulting by	**Maxim Levkov**

Based on the book
"Video Standards: Signals, Formats and Interfaces" by Victor Steinberg
Published by Snell & Wilcox

For further reading we recommend wikipedia.org

About VideoQ

Company History

- Founded in 2005
- Formed by an Engineering Awards winning team sharing between them decades of global video technology.
- VideoQ is a renowned player in calibration and benchmarking of video processors, transcoders and displays, providing tools and technologies instantly revealing artifacts, problems and deficiencies, thus raising the bar in productivity and video quality experience.
- VideoQ products and services cover all aspects of video processing and quality assurance - from visual picture quality estimation and quality control to fully automated processing, utilizing advanced VideoQ algorithms and robotic video quality analyzers, including latest UHD and HDR developments.

Operations

- Headquarters in Sunnyvale, CA, USA
- Software developers in Silicon Valley and worldwide
- Distributors and partners in several countries
- Sales & support offices in USA, UK