ALEXA
CDM Test Chart

WORKFLOW GUIDELINE

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Version History

Version	*Author*	*Changenote*
2011-05-15	Goldstone	First release
2011-05-19	Heugel	Redesign

Introduction

Users of the ALEXA camera often ask if they can use camera test charts like the ChromaDuMonde (CDM) chart from DSC. The results obtained by photographing such a chart with the ALEXA camera differ considerably from the expected results described in the chart's accompanying documentation. Is there a problem?

In short, no. This document describes why those differences occur and how the chart can be used with the ALEXA camera.

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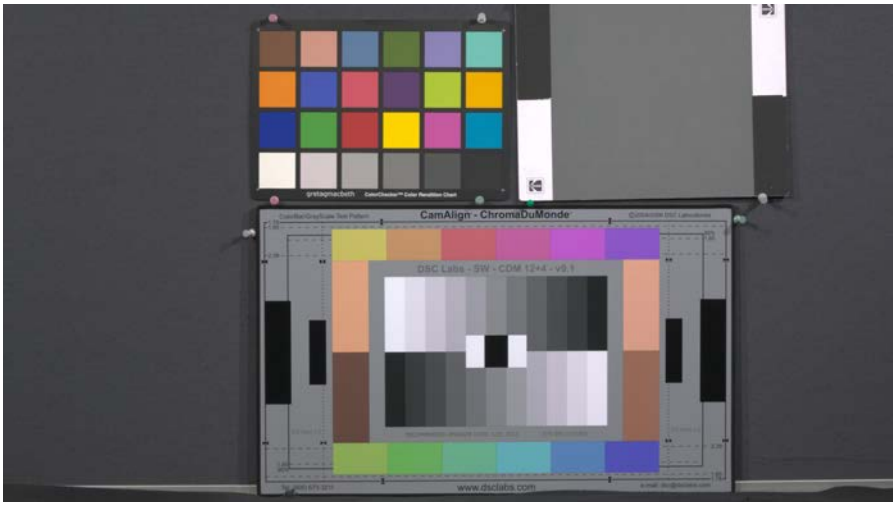
Tone-scale reproduction

The grayscales of the ChromDuMonde chart are designed based on the assumption that the relationship between relative exposure and camera output signal can be described by the equation $y = x^{0.45}$. When this condition holds, the signal levels corresponding to those gray scales will form an ‘X’ on a waveform display, the arms of the ‘X’ will be straight, and their tops will have a signal level of 100 IRE.



The image above represents sensor data processed according to this simple gamma equation.. The white-balanced sensor data were scaled such that the gray portion of the Kodak card was represented by a value of 0.18 (bringing the representation of the white portion of that card to 0.98). The relative values of the gray scale chips in the DSC chart were within 1% of the values documented in the measurements accompanying this particular chart. The gamma of 0.45 was then applied to the image data.

Why 0.45? Possibly because that’s the inverse of the 2.2 gamma that was long presumed to characterize reference displays. In theory, a pure 0.45 gamma in the camera and a pure 2.2 gamma in the display would ‘cancel each other out’.

A camera’s relationship between relative scene luminance and signal is termed its Opto-Electronic Conversion Function (OECF).

The formal standard for video camera OECF, ITU Recommendation BT.709 (usually just referred to as ‘Rec. 709’) is defined in two parts:

$$y = 4.5x$$

for values of x below 0.018 and

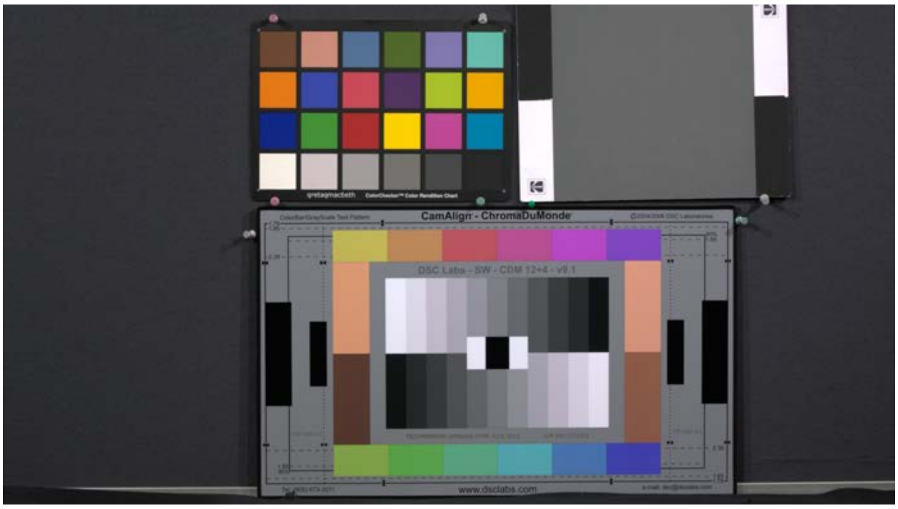
$$y = 1.099x^{0.45} - 0.099$$

for values of x equal to or above 0.018.

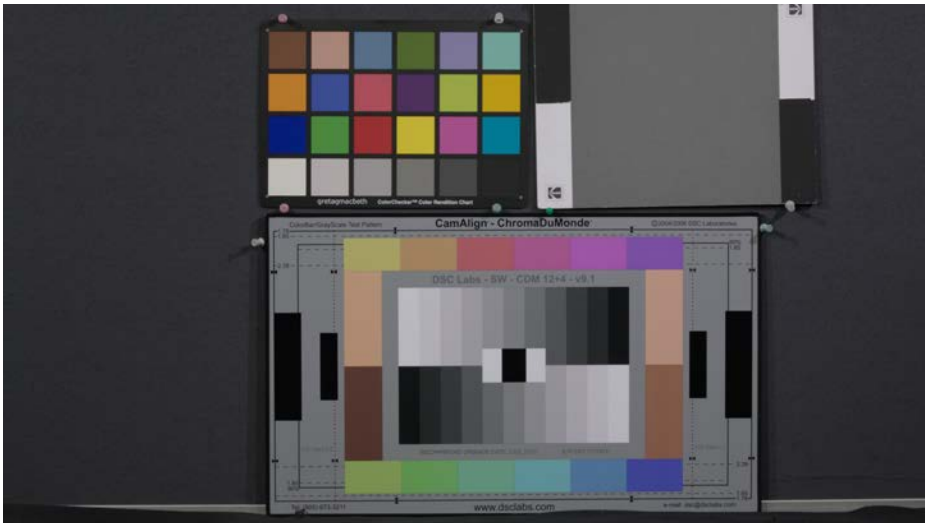
Rec. 709, like the simple ‘pure 0.45’ gamma function, also encodes a 100% white card with a 100% signal.

If one searched for an exponent for a pure gamma function (y^x) that most closely fit the Rec. 709 OECF, the optimal value would be around 0.53. A typical video monitor has a gamma of 2.4 (the ITU seems to settle on a value of 2.35). Unlike the situation described in the previous section, the 0.53 gamma in the camera and the 2.4 gamma in the monitor do not exactly cancel each other out. This is a deliberate design decision; an overall product of camera and monitor gamma greater than one is considered in most circumstances to produce a more pleasing image.

When sensor data are linearly scaled as before, then processed through the Rec. 709 encoding equations, the captured ChromaDuMonde chart is darker than the ‘pure 0.45’ chart, and shows more contrast.

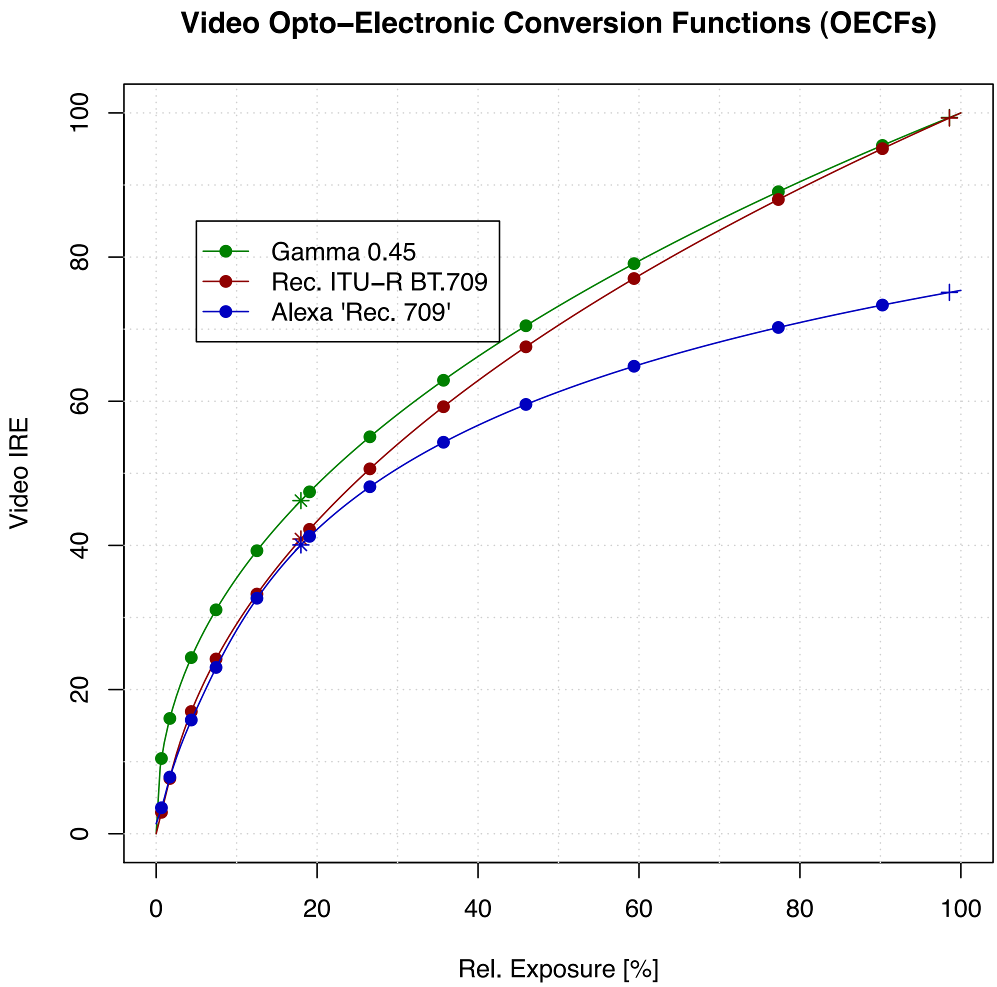


An ALEXA ‘Rec. 709’ capture looks very different:



ALEXA ‘Rec. 709’ encodes a 100% white card below a 100% signal level.

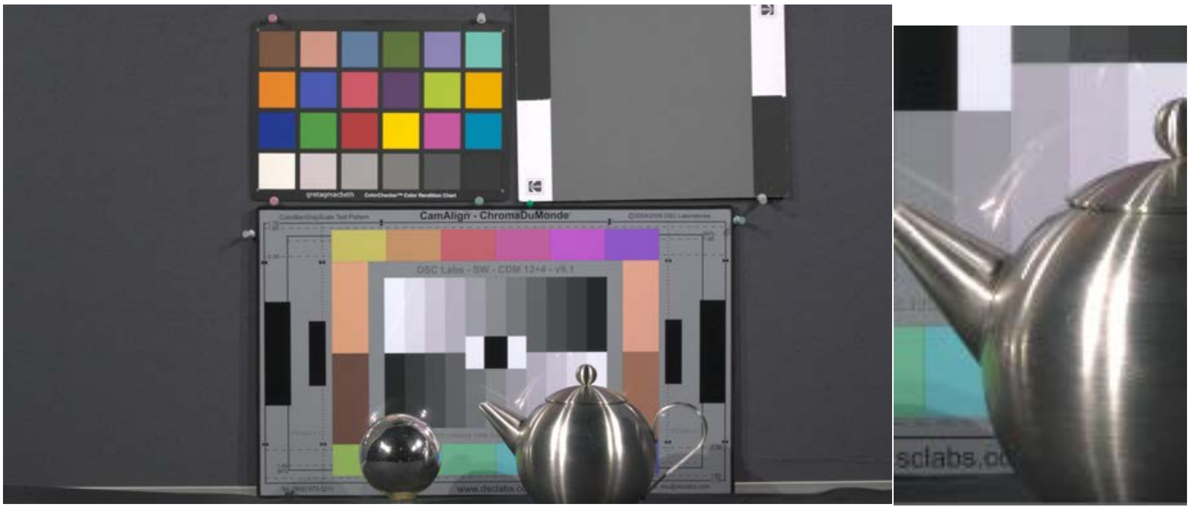
The following chart compares the OECFs of a ‘pure 0.45’ camera, of a camera that implements the Rec. 709 standard, and the ALEXA in ‘Rec. 709’ mode:



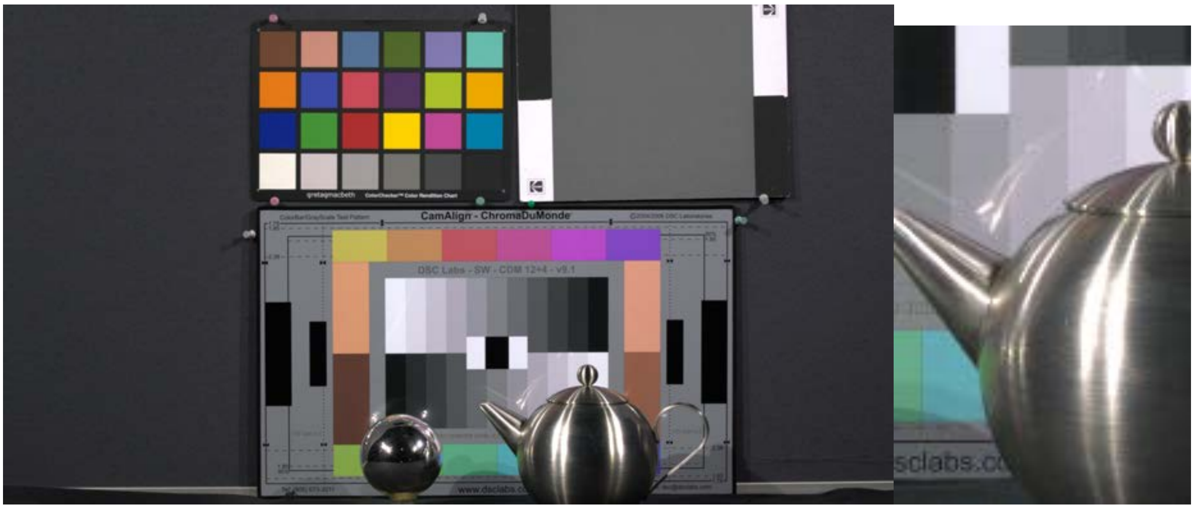
The asterisk marks the 18% gray; the plus sign marks the 100% white.

The ALEXA does not record a 100% scene white with a 100% signal, because it is reserving the upper part of its signal range for highlight information. If we insert objects containing bright highlights into the scene, those highlights are clipped by the ‘pure 0.45’ encoding, and by the ‘strict Rec. 709’ encoding, but not by the ALEXA, as can be seen in the next three images (‘pure 0.45’, Rec. 709, ALEXA ‘Rec. 709’):

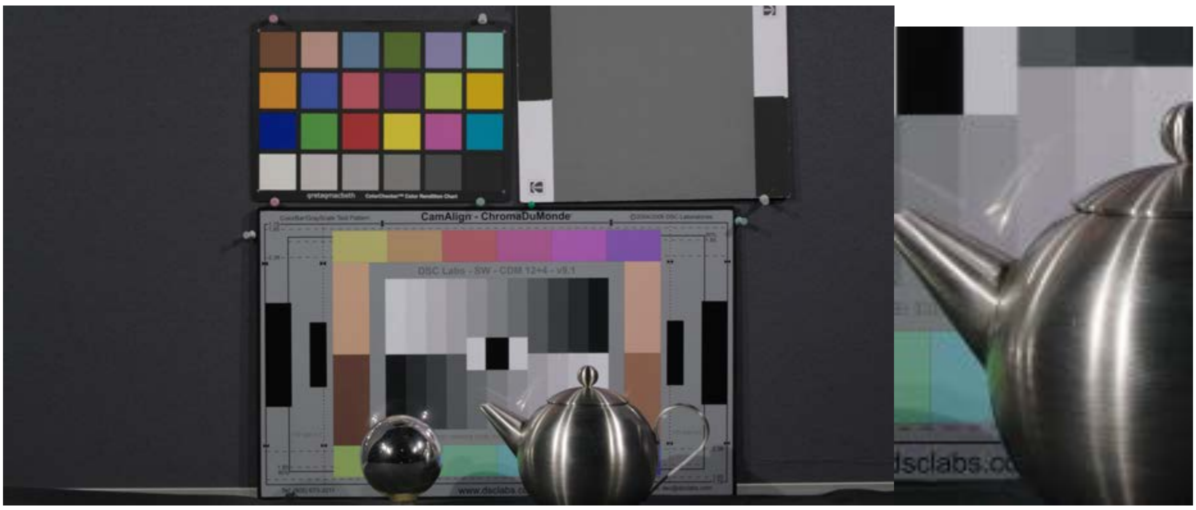
‘Pure 0.45’



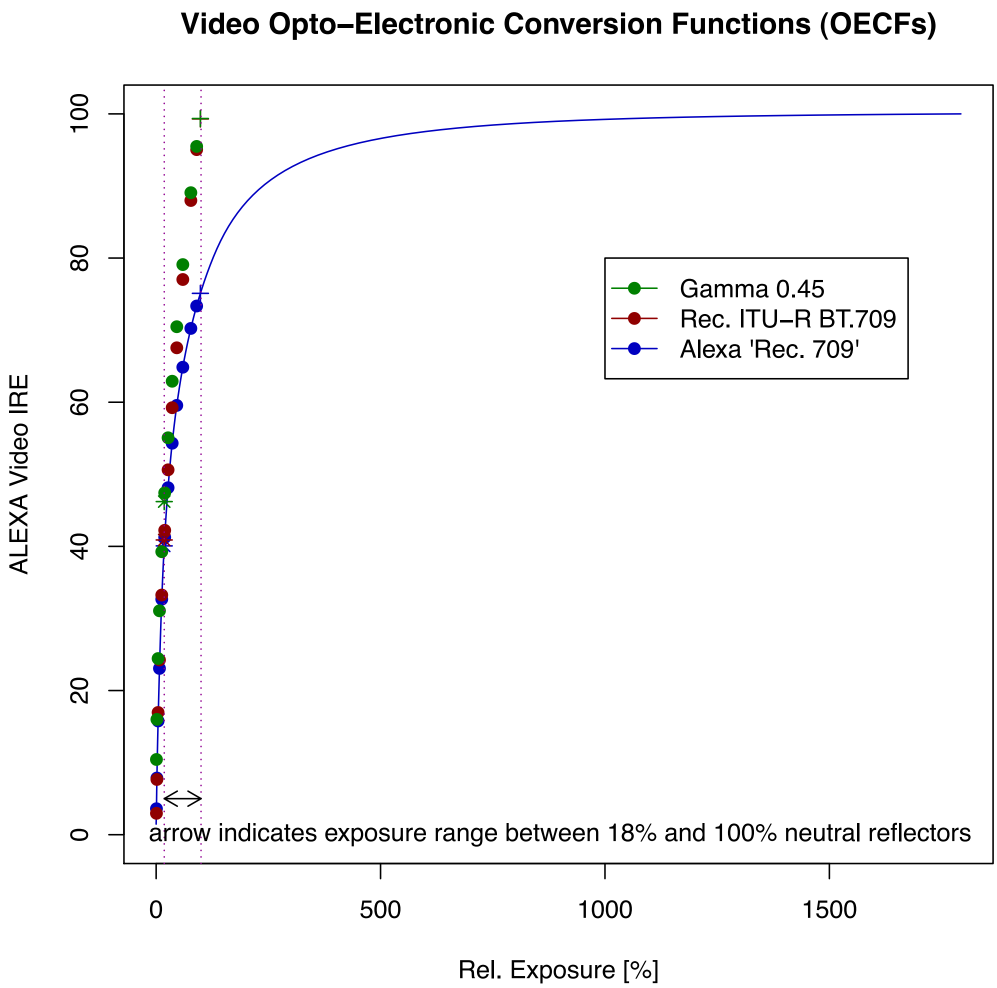
Rec. 709



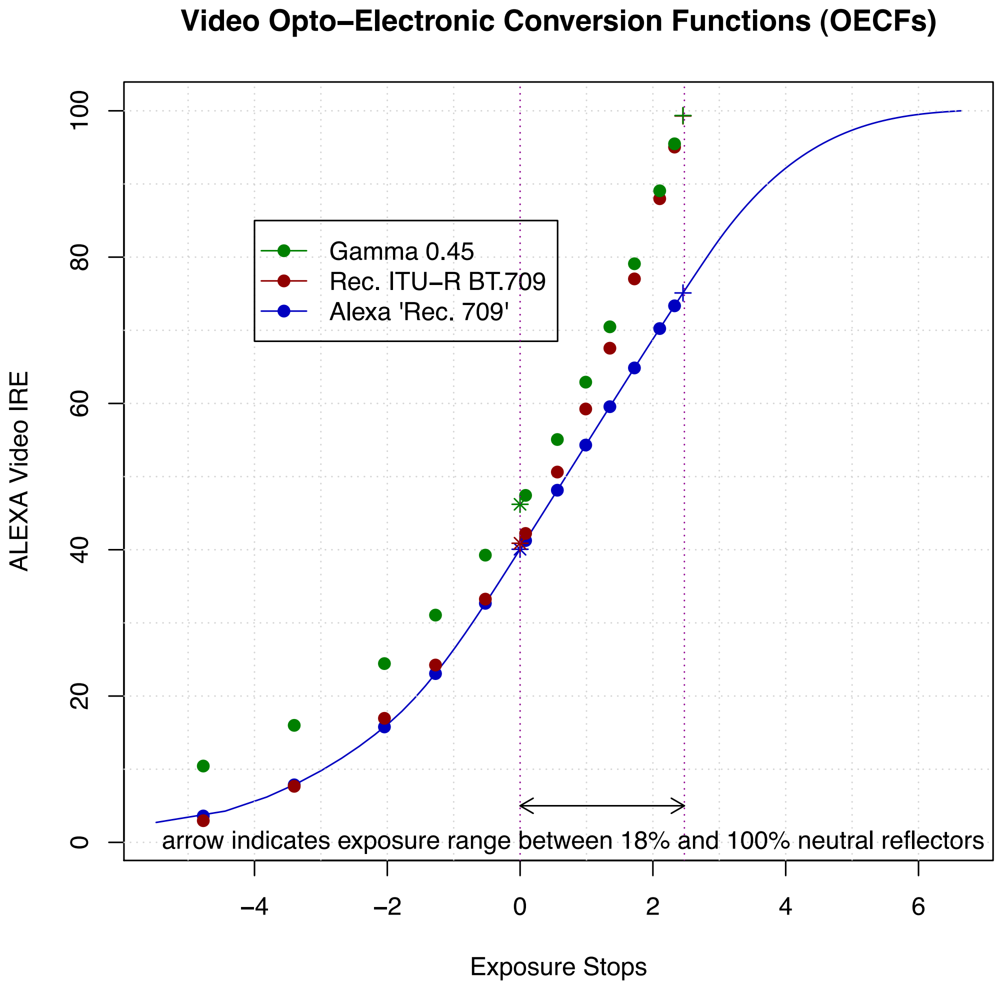
ALEXA ‘Rec. 709’



If we expand the previous graph to include room for highlights, it looks like this:


Video Opto–Electronic Conversion Functions (OECFs)
ALEXA Video IRE
0
20
40
60
80
100
0
500
1000
1500
Rel. Exposure [%]
Gamma 0.45
Rec. ITU–R BT.709
Alexa 'Rec. 709'
arrow indicates exposure range between 18% and 100% neutral reflectors

This capture of high-dynamic-range information is difficult to show in a linear chart. The range of exposure encompassing most interesting image content is squeezed into a very small area of the chart. It helps to convert the linear scale of the x-axis to a log scale such as exposure stops. Mathematically speaking, this is a logarithm to the base 2. When displayed as log exposure instead of linear exposure, the three OECFs look like this:

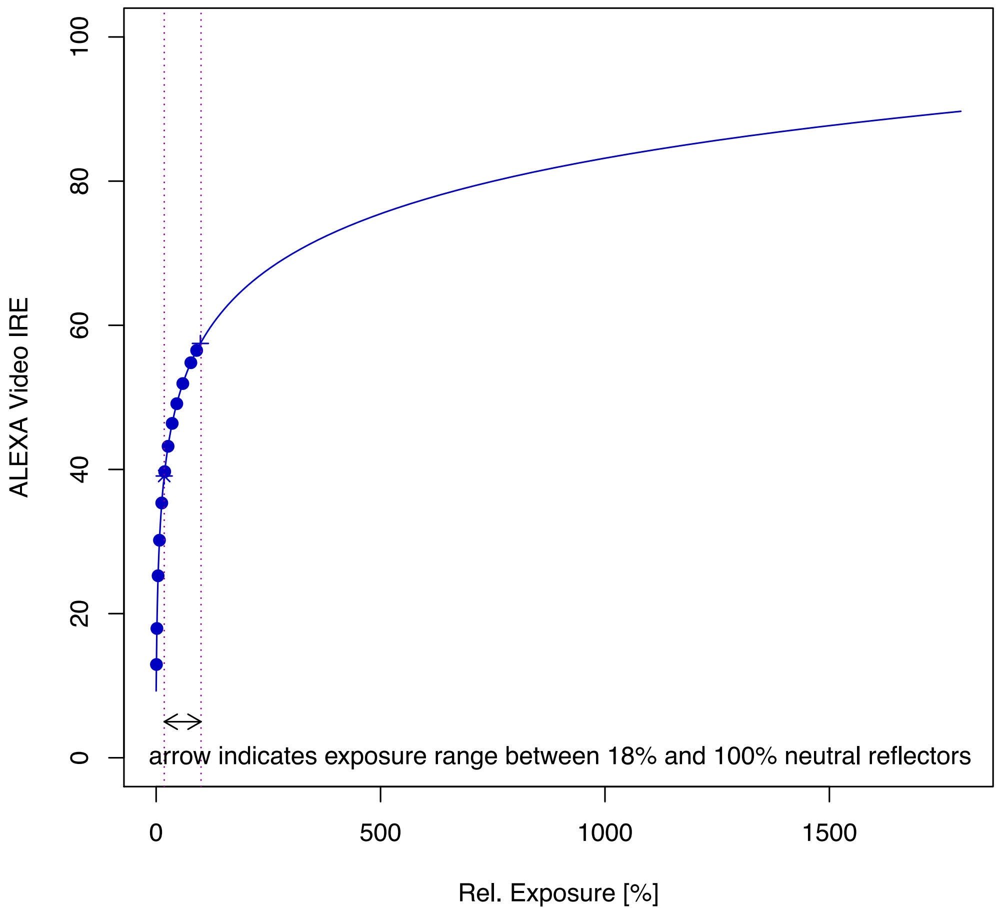


Now the shape of the ALEXA Rec. 709 OECF is revealed. It looks similar to a motion-picture print-through curve. In fact when the ALEXA is producing output in ‘Rec. 709’ mode, the OECF is the concatenation of three curves: the LogC curve (which acts like negative film), a tone mapping curve (which acts like print film), and a compensation for the monitor’s gamma.

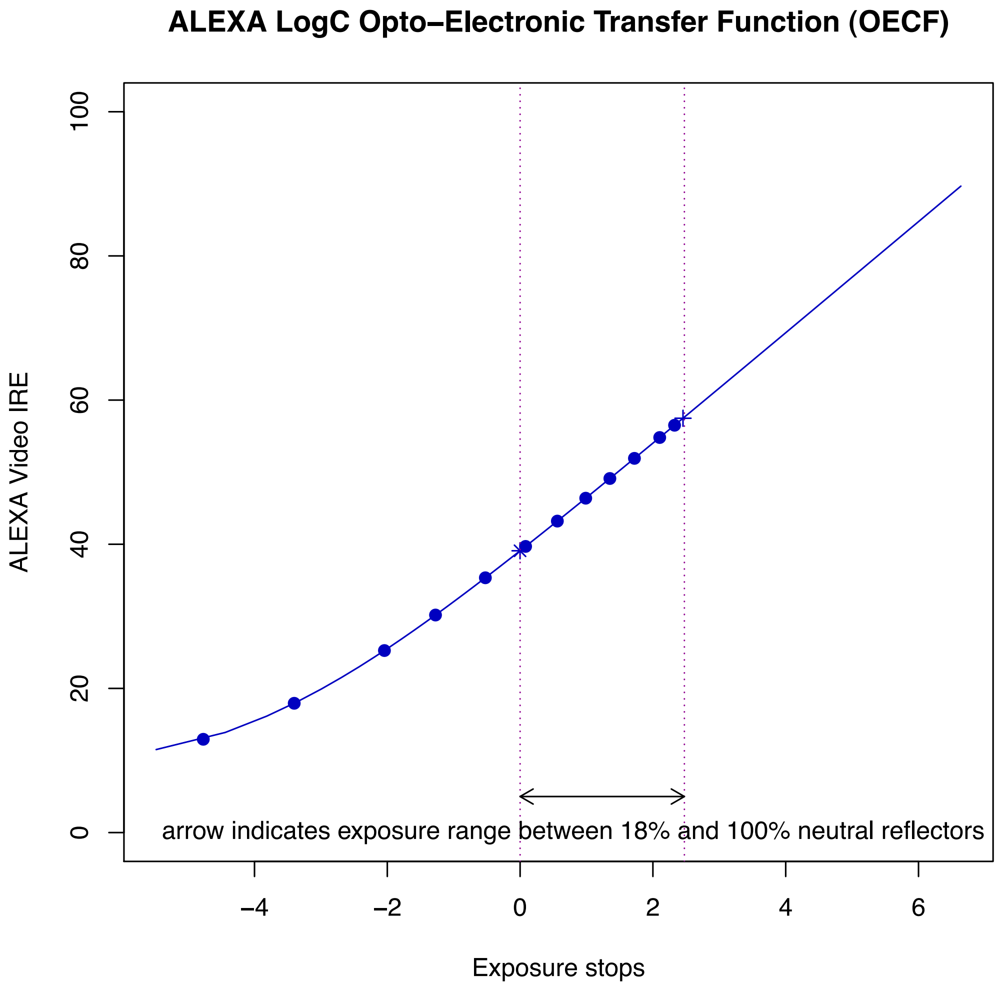
Recording LogC with the ALEXA produces a signal that incorporates only the first of these three curves. A LogC capture of the scene would produce an image that looked like this:

The ALEXA LogC OECF, expressed in relative exposure space, looks like this:

ALEXA LogC Opto–Electronic Transfer Function (OECF)



In log exposure space it looks like this:



Color reproduction

In a display like a CRT or LCD monitor there is a unique relation between the RGB signal and the produced color stimulus.

Surprisingly perhaps, there is no such unique relation when it comes to vision or photography. The human visual system takes some distribution of power in the electromagnetic spectrum and (if that spectrum contains components in what is called the 'visible range') turns that power into the sensation of color. There is no unique distribution to produce a single color; this is what enables, for example, magazines to reproduce the color of grass using green ink instead of chlorophyll, even though the power distribution of the magazine (lit by some reading lamp) and the power distribution of the grass (lit by sunlight) are vastly different.

Very roughly speaking, the human visual system takes such power distributions and reduces them to three signals. This human visual response that defines how this process works is given a special designation: such a response is said to be colorimetric.

Camera systems (both for still photography and for motion pictures) also take power distributions and reduce them to three signals. Unfortunately, the camera system's 'visual response' differs from that of humans; camera system response is not colorimetric. To make matters even more complicated, the response of a camera from manufacturer A will be different than that of a camera from manufacturer B.

As a result, it's not possible to have a real-world color stimulus (which, again, is a distribution of power in the electromagnetic spectrum) be captured identically by all possible cameras. The aim values for the colors in the ChromaDuMonde chart assume a colorimetric camera response. The ALEXA response will differ from those aims, as would (in differing ways) those of any other type of camera.

Some cameras allow adjustment of their response. This can be used to more closely match (for a given set of stimuli, like those on a test chart) cameras to each other, or to some external standard response such as that given in the documentation accompanying the chart. But taking two cameras and achieving a matched response for the color stimuli provided by a test chart does not guarantee that colors other than those on the chart will match. (It does not even guarantee that the match of test chart colors will hold up if the chart illumination changes.)

The implications of cameras having a non-colorimetric response, and of different cameras having different non-colorimetric responses, include at least the following:

- Two types of objects might appear to be the same color to the human eye, but that does not imply that they will be captured as the same color by a camera system.
- Two types of camera system may capture the same object, but that does not imply the captured color will be the same.
- Two types of camera system may capture the colors of a test chart to produce similar values, but that does not imply a match of colors other than the test chart's colors.
- A match in a camera system's captured color between two objects (or between two capture systems' capture of the same object) does not imply that such a match will be maintained across a lighting change.

The reproduction of colors of critical objects like costumes should be tested with the particular type of digital camera to be used by production. Don't rely on test charts (and don't rely on experience with film, which has its own unique color response).

Use of the chart

We have demonstrated that the OECF of the ALEXA differs (for good reasons) from a simple gamma law and from the formula specified in Rec 709. And we discussed how the color reproduction of cameras (with their various non-colorimetric responses) can't be easily verified by a test chart.

Nevertheless, test charts like the ChromaDuMonde are still useful in checking the consistency of production and post-production:

- Photographing such a chart in each scene can help to detect unintended transformations applied to the images.
- The grayscale patches can be used to verify that different post-production software packages are, for example, calculating acceptably close average patch pixel values when linearizing LogC data.
- The color patches can be helpful in detecting unusual lighting situations where the colors appear very differently than in other scenes recorded with the same camera.

Finally, the chart can also be useful to detect variation between different camera units of the same type, which may be caused by a malfunction.