High Dynamic Range (HDR) in the EOS C700 and EOS C300 Mark II Cameras PART 2

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CINEMA EOS

Deep Dive

into

High Dynamic Range (HDR)

of

EOS C700 and EOS C300 Mark II Cameras

PART 2

Content

Abstract

The companion white paper "Deep Dive into High Dynamic Range – Part 1" examined key aspects of the image sensor that is capable of originating HDR video. The importance of choosing a reference base sensitivity setting for the HDR camera and its implications on the dynamic range actually delivered by the camera were also discussed. It was emphasized that this linear light digital representation predetermines three critical specification of the Luma video that is ultimately delivered by the camera – namely, sensitivity, dynamic range, and noise.

Motion picture film offered the ability to capture impressive levels of HDR imagery on the film negative. The challenge was to preserve the essence of this imagery to the degree possible on to the final positive film print – which was quite limited from an HDR viewpoint. This dilemma was addressed over many decades by skillful "mapping" of the original image capture to the known attributes of the final film medium (and indeed to the equally known attributes of the projection systems). Choosing specific film stocks (often a number of the same in one production) and employing refined strategies in the film lab could produce reasonably compelling final imagery within the dynamic range constraints of the overall film system. Cineon expanded these options when it introduced digital scanning of film negatives and increasingly sophisticated color grading capabilities in postproduction.

The Ultra High Definition Alliance (UHDA) recently published HDR specifications for contemporary OLED and LCD consumer UHD displays. Of particular significance are the extreme low black levels specified for each display – being 0.0005 nits for the OLED and 0.05 nits for the LCD. HDR in the realm of digital motion imaging can, when appropriate care is exercised, be largely preserved through to the final delivery medium and capitalize on the HDR capabilities of the latest displays.

Not all scenes require extreme highlight reproduction simultaneously with the reproduction of color and textural details in very dark regions of that scene. Some scenes do need to favor extreme brightness and highlights. Other scenes seek reproduction of textures and color detail in often quite dark environments or deeply shadowed portions of a scene.

This white paper pays particular attention to the latter portion of the camera system and the management of extreme low signal levels that can be originated by the EOS C700 and EOS C300 Mark II cameras. Central to that management is the choice of camera OETF
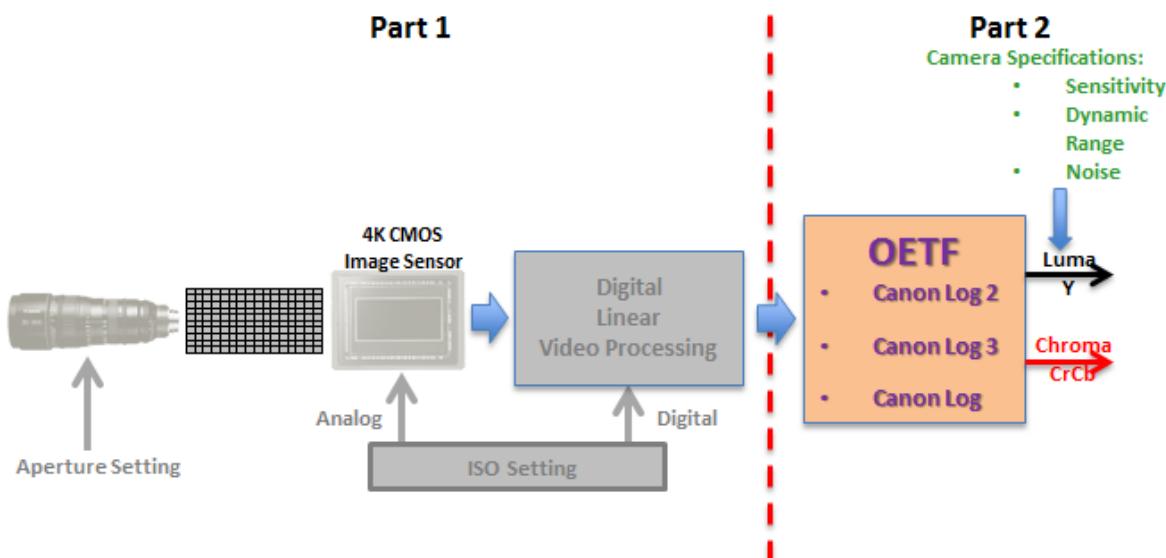
1.0 LOGARITHMIC OETF – INTRODUCING CANON LOG 2 AND CANON LOG 3

The discussions in the White Paper (Deep Dive Part 1) centered about the all-important linear representation of the camera video. Now that video must be further "prepped" in a manner that can help ensure that the extensive dynamic range created by the imaging system will be fully protected while being recorded – and also as it is transported over industry standardized interfaces. This is the primary role of the camera's Optoelectronic Transfer Function (OETF). Figure 1 shows the three different logarithmic OETF curves that can be selected in the EOS C700 and EOS C300 Mark II cameras.
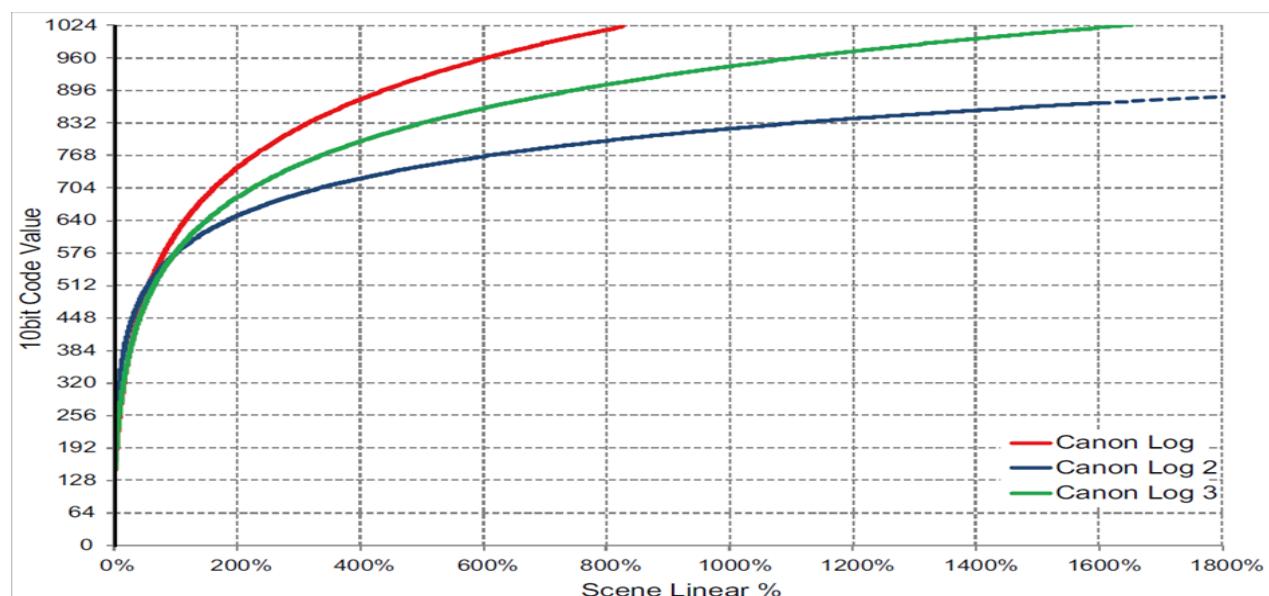

Figure 1 *Showing the three Canon Log curves that can be selected in the EOS C700 and EOS C300 Mark II cameras*

Canon Log [1] is the curve designed for the original EOS C300 camera (shown in red in Figure 1) and was optimized for the 8-bit representation of that camera. It was structured to manage the 800% dynamic range (relative to 100% reference white) capability of that camera. It is included in the EOS C700 and EOS C300 Mark II cameras to facilitate close matching with the EOS C300 camera.

Canon Log 2 (blue curve in Figure 1) was subsequently developed to manage the 15-stop dynamic range of the EOS C300 Mark II camera [2]. It encompasses the 1600% dynamic range of this camera (and the EOS C700 camera) and the lower region of the curve is optimized for the additional exposure latitude in the lower regions. This curve also extends two stops above the 1600% capability of the image sensor to allow for additional flexibility in postproduction image manipulation – which we term a Sensitizing Margin.

Canon Log 3 (green curve in Figure 1) was added to both the EOS C700 and EOS C300 Mark II cameras to offer an alternative when the full 15-stops of dynamic range is not required – especially in the deep dark areas of a scene. This allows for a more simple level of grading in postproduction.

The lower regions of these three log curves have been carefully tailored to support creative choices when considering the nature of image capture in dark areas of a scene. Figure 2 shows a semi-log representation of the three curves centered about the 18% reference gray reflectance that better reveals the differences in the lower portions of these curves.
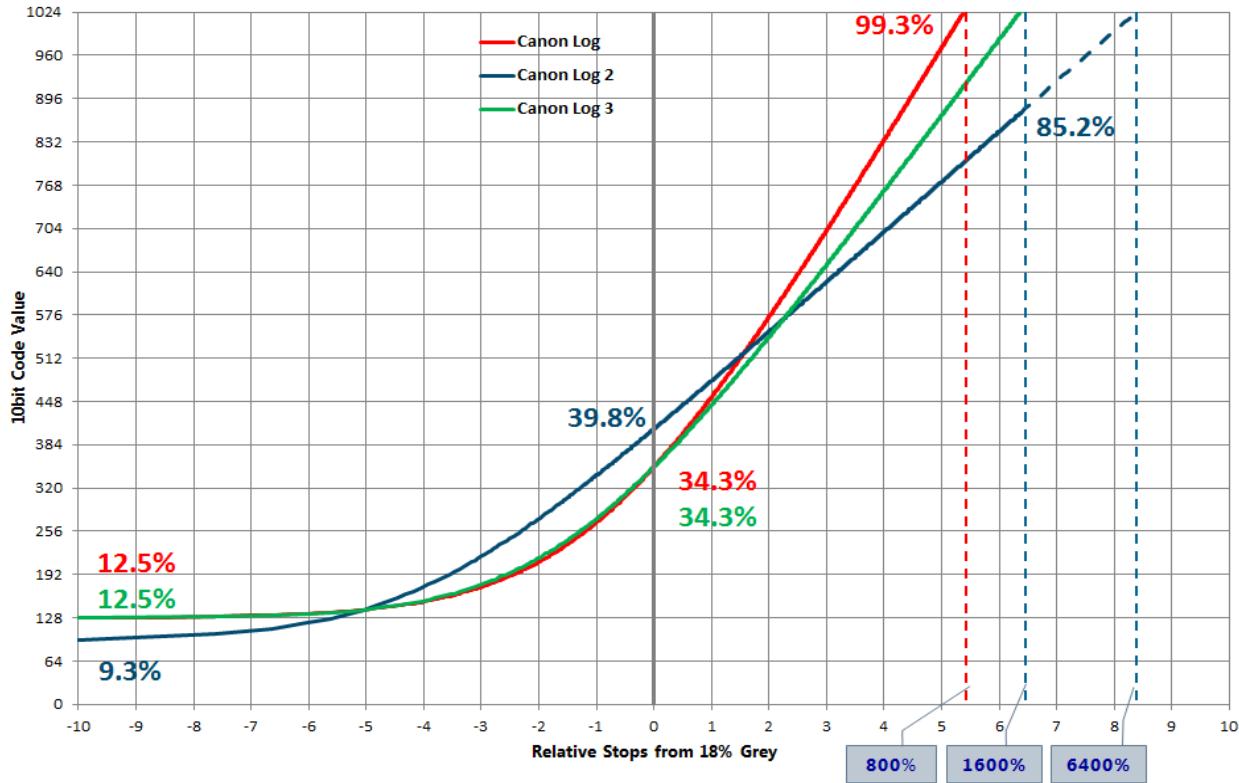
Figure 2   *Showing the same three Canon Log curves in semi log form*

For this discussion, attention is drawn to the Canon Log 2 and the Canon Log 3 curves shown.

With respect to the Canon Log 2 curve four key points to note are:

1. At the lower end, the curve extends down to almost 9-stops below the 18% reference gray

2. At the upper end – the curve itself extends to 8.3 stops above reference 18% gray although the image sensor saturates at 6.3-Stops (this is termed the 2-Stop Sensitizing Margin).

3. The 18% reflectance reference gray has a digital code of 407 (corresponding to 39.8 %)

4. The straight portion of the semilog graph is the wider of the three – close to that of film

With respect to the Canon Log 3 curve:

1. It extends to 6.3-Stops above the reference (coinciding with the 1600% sensor saturation level)

2. At the lower end, the curve merges into that of the Canon Log curve and effectively ends at about 7-Stops below reference gray

3. The 18% reference gray has a digital code of 351 (corresponding to 34.3 %).

3

2.0   DEEP DIVE INTO CANON LOG 2

The significance of the difference between the lower ends of the two curves becomes evident when they are examined with respect to the image sensor signal level capability and associated noise level.   Figure 3 reproduces the linear signal levels and noise of the image sensor that are associated with the lower three Stops of its 15-Stop dynamic range – before they are transformed by the OETF.
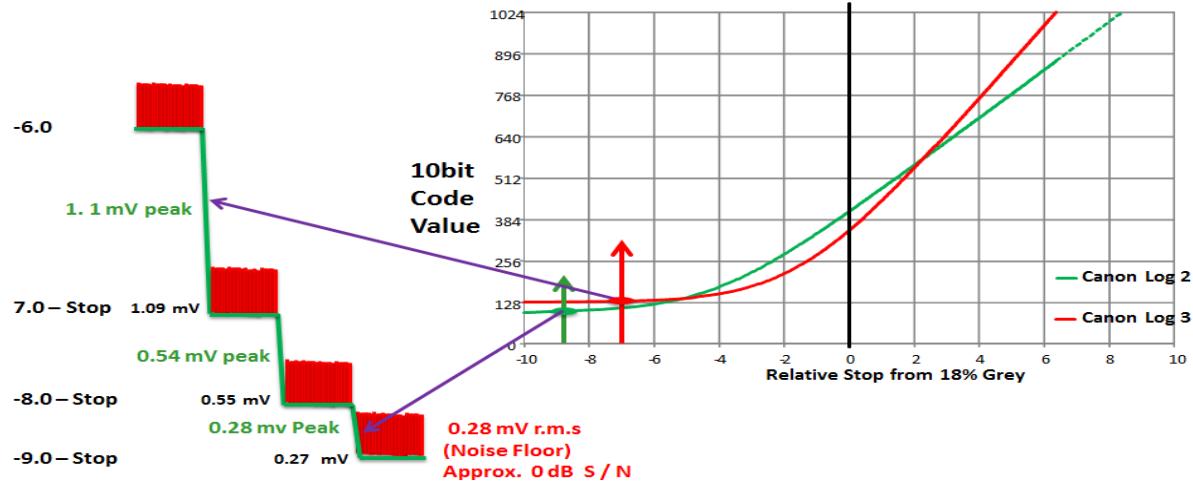

Figure 3   *Shows the lower T-Stops signal level capability of the EOS C300 Mark II image sensor and where they   align with the Canon Log curves*

Looking more closely at the Canon Log 2 lower curve in Figure 3 – it will be noted that it extends almost 9-stops below the reference 18% gray.   Accordingly, it reproduces the lower effective Luma limit of 0.27 mV – where S/N reached unity – of the image sensor output (8.7-Stops below 18% reference). Accordingly, in productions that seek such low video signal levels the Canon Log 2 should be employed.
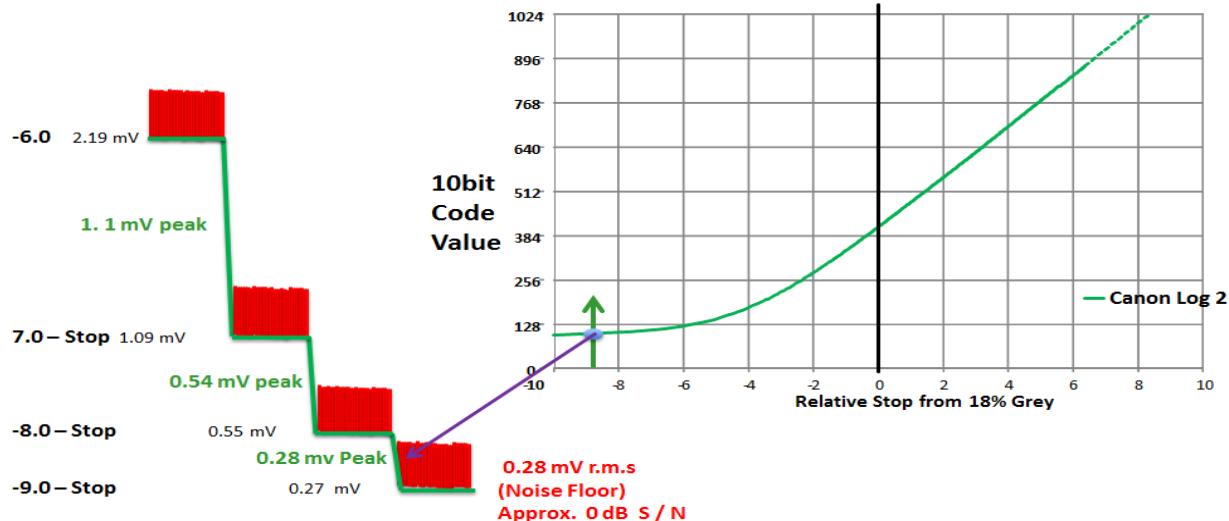

Figure 4   *The Canon Log 2 extends almost 9-Stops below reference 18% gray and accordingly it reproduces the image sensor level where the S/N becomes approximately unity*

It must be noted that while the Canon Log2 curve can discern these extremely low video levels the gain of that curve down at those low levels become quite high and will significantly elevate the visibility of the noise in these dark regions. This deep dive down into such low regions of signal levels immediately poses the question as to how realistic are considerations of signal levels of such low amplitude in the real world of video production. Can they even be seen on a video display screen? This becomes more important when they are immersed in high noise.

A first subjective calibration on the visibility of such video signal levels is offered in Figure 5. This is a reproduction of a test recently conducted. Here, an EOS C300 Mark II camera was exposed for 100% Luma level on the 90% reflectance chip. A 6-stop ND filter was then switched in and that produced the image shown below. The signal is clearly quite noisy. What is important, however, is that every step in the gray scale on the bottom row is still clearly discernible. Contemporary grading systems would have little difficulty in extracting those last two levels of that gray scale chart.
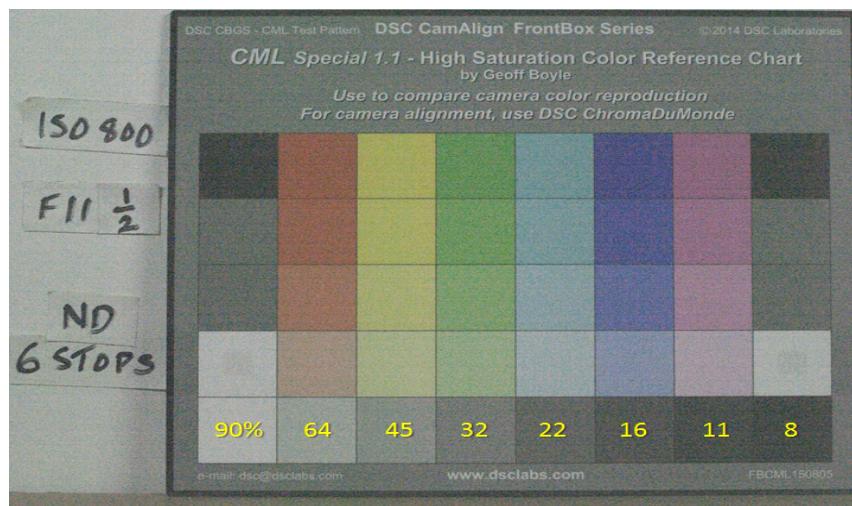

Figure 5   *A 6-stop ND filter switched into a nominally exposed chart places the black chip at 9.5 stops below 100 IRE reference white level*

Figure 6 below shows a test chart with close to 0 dB signal to noise in the lowest black level – this noise would be subjectively higher on a live motion image. However, visibility of the chart is still evident and modern sophisticated grading techniques will readily extract that signal and clean up the noise
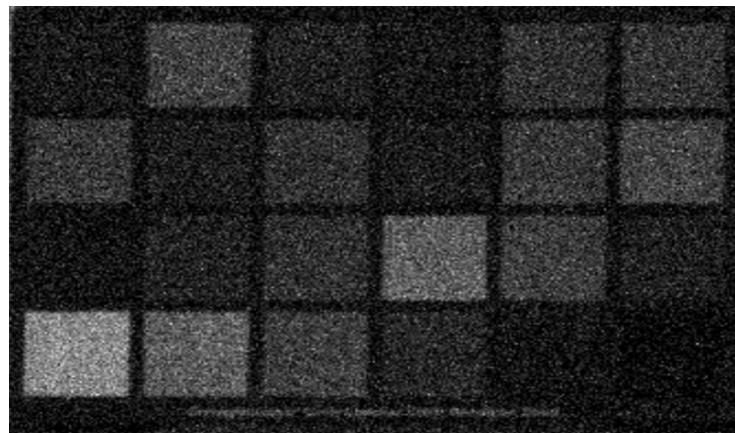

Figure 6   *A test chart with close to unity signal to noise ratio (0 dB S/N) at the lowest black level*

A subjective judgment on the camera ability to discern shadowed detail is "if you can see that detail on the n-set reference display – no matter how faint – it is real and it can be recovered".

It is arguable whether such low video signal levels serve a useful purpose in program genres like broadcast news, sports, documentaries etc. But, in movie-making and television episodic production detail in deeply shadowed scenes can be of high aesthetic importance. Producers and directors will go to considerable lengths in postproduction grading to render such details sufficiently visible as to contribute to their subtle story-telling aspirations. Moods within storytelling are often portrayed with skillfully created dark scenes. Figure 7 shows some examples of such scenes. A close examination of each will reveal a great deal of image detail in the dimly illuminated faces, as well as the texture of clothing, curtains, and walls that are extremely dimly lit.

Figure 7   *Showing two scenes from dramatic stories that sought a dark mood while also portraying important textural and color details in face, hair, and clothing*

However, there are also many program genres (especially in the television production world) where the need for extremely low level signals is not required. Here it makes sense to impose a practical limit that removes them and the relatively higher noise levels associated with them. This makes any subsequent grading more simple and less time-consuming. It is for this reason that the separate Canon Log 3 OETF has been included in the camera.

3.0   DEEP DIVE INTO CANON LOG 3

As shown in Figure 8 Canon Log 3 curve (like that of the original Canon Log) extends to about 7-Stops below reference gray – a similar characteristic to the Canon Log curve. Accordingly it does not pass the lower two steps of the 15-stop range of the image sensor.
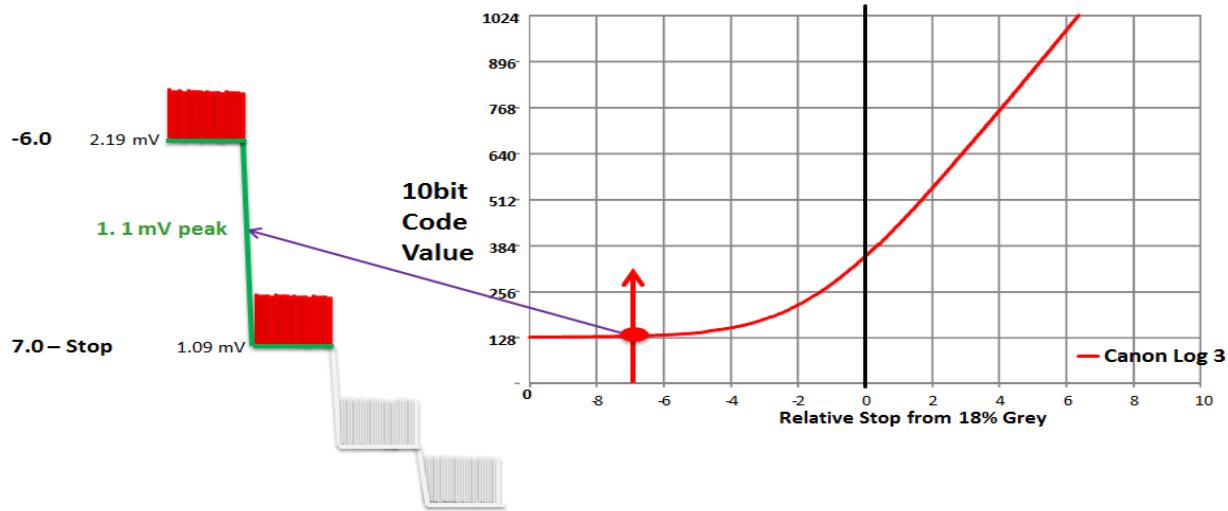

Figure 8   *Showing the curtailment of the lower end of Canon Log 3 curve and how it eliminates signals below the -7.0-Stop level*

The slope of the Canon Log 3 curve is about twice that of the Canon Log curve at the extreme lower end. The upper dynamic range of 1600% is supported – just as it is in Canon Log 2, but the additional head room of the latter curve is removed from Canon Log 3.   Canon Log 3 bottoms out at 7-stops below reference 18% gray and it extends to the saturation limit of the image sensor at the upper end – that is, to +6.3 stops.   Accordingly, this curve supports a dynamic range of greater than 13.0-stops.

4.0   CAMERA SENSITOMETRIC CHARACTERISTIC

The various Canon-Log curves are perceptually uniform digital transfer characteristics that transform the high-bit depth per RGB color component linear signals into a quasi-logarithmic nonlinear transfer function. Mapping from the original 14-bit depth to a 12 or 10-bit output using the mathematically prescribed Canon Log2 is the method used to achieve the level of bit rate reduction that supports uncompressed recording and also delivers the various camera output formats via a standardized 3G SDI serial interface.

Sensitometric characterization of a camera system speaks to the overall performance specifications of the final camera output signal – a combination of output Luma sensitivity, dynamic range, and signal to noise. Accordingly, it assumes that the camera OETF has been applied. These specifications apply to the camera output signal after it has been restored to a linear representation.

The Sensitometry characteristic maps the disposition of dynamic range (or exposure latitude in cinematography terms) above and below the 18% reference gray level.   It is a mapping that immediately shows the sensitivity of the camera – the lowest level in stops at which it can reproduce a useful signal level at a given ISO setting.   It also shows the available overhead in stops above the reference 18% gray at that ISO setting.
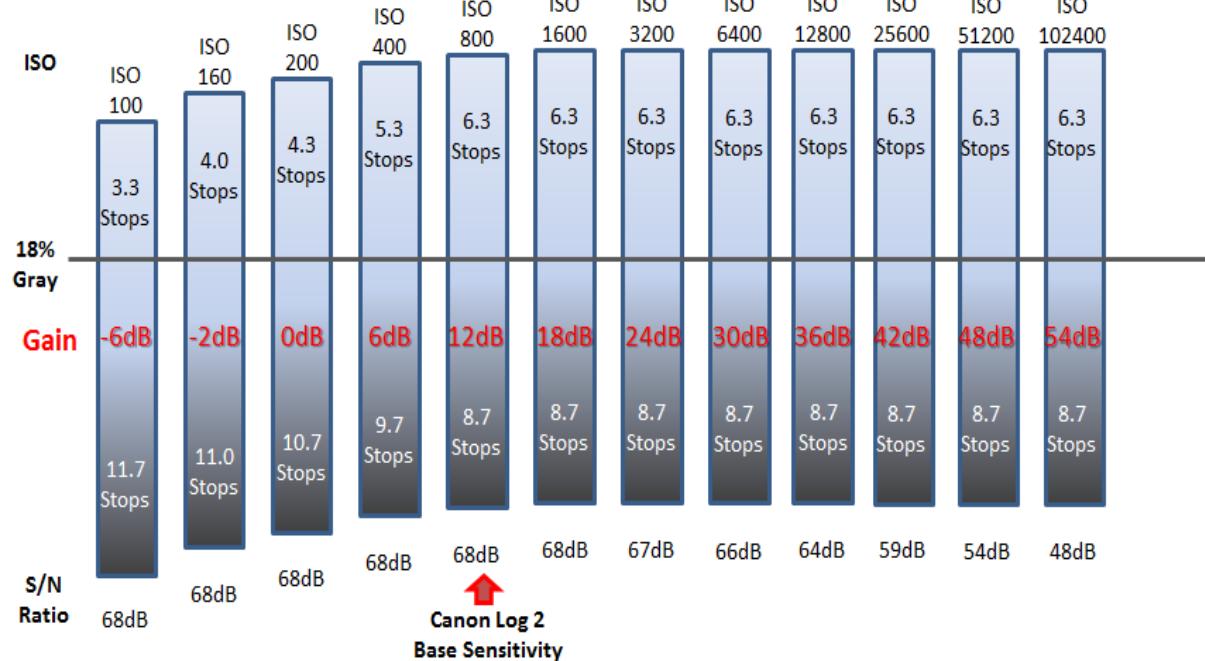

Figure 9   *The Sensitometric characteristic with increasing ISO settings for the C700 camera*

In the case of the EOS C700 camera, the base sensitivity was chosen to provide the optimum disposition of exposure latitude above and below the 18% reference gray level – as shown in Figure 9. This occurs at ISO 800 (Master Gain set to +12 dB).

At this ISO 800 setting the formal sensitivity specification of the EOS C700 camera – in *traditional television terms* is:

   With 2000 Lux of illumination at 3200 degrees Kelvin,

   Camera set for 1920 x 1080 @ 29.97P, 1/30 second shutter speed

   The lens setting to achieve 100% Luma is ***F-14.0***

   Luma signal to noise is ***68 dB***

This is an excellent camera sensitivity specification.

In Figure 9 the Luma signal to noise performance is listed at the bottom of each of the ISO settings. It can be seen to remain constant all the way up to ISO 1600, and alters only fractionally up to ISO 6400. The EOS C300 Mark II is identical in all respects except that the Luma signal to noise is less by one dB for each ISO setting.

5.0 SUMMARY

The EOS C700 and its companion mobile camera EOS C300 Mark II have a 15-stop specification for their dynamic range. This supports capture of image detail at brightness levels more than 6-stops above the 18% reference gray and more than 8-stops below that same reference. The cameras can select between a number of OETF logarithmic transfer characteristics depending upon the nature of a given scene illumination and the nature of the production.

Canon Log

Canon Log is a logarithmic curve that is installed in all of the Cinema EOS cameras, the XC10 and XC15 professional-use digital video cameras, and also the ME20 series of multi-purpose cameras. This curve supports more than 5-stops above reference gray (or 800% above reference white) and more than six stops below reference gray. This OETF uses Code 128 (10 bits) for 0% black, and it is designed so that on-set monitoring of details in the dark areas in images is readily visible. It is ideal for productions that seek relatively simple grading in postproduction.

Canon Log2

Canon Log 2 was specifically designed to exploit the full imaging capabilities of a 15-stop dynamic range in support of HDR image capture. It helps ensure capture of subtle gradations in deeply shadowed areas of a scene, while at the upper end the curve extends beyond the 1600% limit of the image sensor to support image manipulation in the grading process (sensitizing margin) – allowing gradations at that upper end to be made brighter if desired. This curve uses the Cineon digital negatives [3] as a basis and, with its use of Code 95 (10 bits) for 0% black it fits in well with the Cineon digital film system. This OETF is ideal for those productions that seek exploitation of details in dark shadowed scenes to support creation of moody scenes common to high end episodic television dramas and in many theatrical motion picture productions. It anticipates sophisticated image grading to appropriately adjust those details to meet creative aspirations.

CanonLog3

Canon Log 3 is intermediate between Canon Log and Canon Log 2. This transfer function supports the full 1600% upper limit of the image sensor (one-stop more than the Canon Log curve), but at the lower end, the curve devolves into that of the Canon Log characteristic – retaining the same operational simplicity as that gamma curve. Table below summarizes the salient differences between the Log curves.

	Canon Log	Canon Log 2	Canon Log 3
OETF Format	800% (5.3 stops)	6400% (8.3 stops)	1600% (6.3 stops)
C700 / C300 Mark II	800% (5. 3stops)	1600% (6.3 stops)	1600% (6.3 stops)
Sensitizing margins	—	2stops	—
18% Gray Level	34.3%	39.8%	34.3%
Black Level	12.5%	9.3%	12.5%

Conversion of Log Curves to other Standardized Curves

Canon has released 1D LUTs for conversion from Canon Log, Canon Log 2 and Canon Log 3 to Linear, Cineon, BT.709, DCI, and Wide DR. It has also released 3D LUTs that include color gamut conversion. All details are available on the Canon website

REFERENCES

[1]   Canon White Paper   *"Canon-Log Cine Optoelectronic Transfer Function"*
       http://learn.usa.canon.com/resources/articles/2012/cinemaeos_white_papers.shtml

[2]   Canon White Paper   *"Image Performance Enhancements in the C300 Mark II Camera"*,
       http://learn.usa.canon.com/resources/articles/2012/cinemaeos_white_papers.shtml

[3]   *"Grayscale Transformations of Cineon Digital Film Data for Display, Conversion, and Film Recording"*
       Version 1.1   Cinesite Digital Film Center,   April 12, 1993