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WHITE PAPER

CINEMA EOS

High Dynamic Range (HDR) in the EOS C700 and EOS C300 Mark II Cameras PART 1

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CINEMA EOS

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Deep Dive

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

Part 1

Abstract

In 2015 the EOS C300 Mark II camera was introduced and offered a digital motion imaging system intended to support High Dynamic Range (HDR) and Wide Color Gamut (WCG). Canon subsequently introduced the flagship EOS C700 digital cinematography camera at IBC2016 – close to the fifth anniversary of the November 2011 introduction of the Cinema EOS system that now includes an extended family of cine lenses, cameras, and reference displays. The EOS C700 offers broader 4K imaging options than the EOS C300 Mark II, significantly extended recording options, expanded system interfaces, and multiple operational features sought in an A-Camera. The EOS C300 Mark II flanks the EOS C700 as a mobile and versatile companion B-Camera. These two cameras share the same Super 35mm 4.5K CMOS image sensor developed by Canon to achieve a 15-Stop dynamic range. This paper will review some of the innovative technologies underlying the image sensor design that supports this extended range.

HDR and WCG are still in their early day and presently command wide attention in terms of their promised enhancements to digital motion imaging. An inevitable learning curve associated with skillful deployment of these imaging enhancements preoccupies many in the creative communities – in both theatrical motion picture production and high-end television episodic production. New questions related to ISO settings, noise, and the exposure latitude both above and below reference exposure levels (18% gray for the digital cinema world and 100% reference white for those in HDTV and UHDTV production) are much discussed.

Many readily associate with the enhanced highlight details that new HDR display technologies can effectively reproduce. But, HDR simultaneously extends exposure latitude down into quite dark scenes and this too offers important new creative options. This white paper is focused on the front end of the camera system – both the linear light representation of the new CMOS image sensor and the subsequent linear video representation within the camera processor. Particular attention is paid to the exposure latitude below the reference exposure level as these cameras have increased this a further two-stops beyond that of the early EOS C300 camera.

Special attention is paid to the management of image sensor noise as ISO exposure is raised – a strategy that sustains a high Luma signal to noise up to ISO 6400. A companion paper will examine the final prepping of the HDR capture in the form of a choice of nonlinear Opto Electronic Transfer Functions (OETF) and their implications for the overall sensitometric behavior – which combines the sensitivity, dynamic range, and signal to noise specifications of the final Luma video signal delivered by the cameras.

1.0 INTRODUCTION – THE HDR CAMERAS in BRIEF

The EOS C700 and EOS C300 Mark II cameras share four advanced imaging attributes [1]:

1. Origination of HDR and WCG imagery

2. On-board recording to include 2K / HD / 4K / UHD options at all standard frame rates

3. RAW recording options

4. Capability to operate in ACES 1.0 space

Figure 1 *The EOS C700 digital cinematography camera – Canon's flagship A-Camera*

The EOS C700 supports 4K / UHD / 2K / HD on-board recording with a choice of either XF-AVC or ProRes [2] codecs using two Cfast 2.0 cards. An optional Codex CDX-36150 dockable recorder allows capture of uncompressed 4K RAW @ 12 or 10-bit up to 120 fps. 15-Stop dynamic range helps ensure excellent HDR acquisition and a choice of four color gamuts (including two wide gamuts – the ITU-R BT.2020 and the Canon developed Cinema Gamut) supports a diversity of creative aspirations in both television and movie production. The companion EOS C300 Mark II B-Camera supports on-board capture of 4K / UHD / 2K / HD using the Canon XF-AVC codec – also on CFast 2.0 cards [3]. It offers the same 15-stop dynamic range and the same choice of four color gamuts. 4K RAW recording is supported by a standardized 3G-SDI interface to a choice of external recorders.

Figure 2 *The C300 Mark II camera – a companion B-Camera to the C700*

The Super 35mm CMOS image sensor design paid specific attention to a linear light representation of high dynamic range scenes. Innovations within the second generation proprietary photodiode design in combination with new on-chip noise cancellation technology have simultaneously lowered the noise floor and elevated the sensor saturation level. These strategies provide a definitive ***15-Stop*** dynamic range capability in this digital cinema camera. Further, a unique control over the image sensor noise floor as the exposure is raised allows the ISO range to be extended up to ***ISO 102,400.***

2.0 THE IMAGE SENSOR AND THE CAMERA

The challenge to the camera designer is to appropriately map the image sensor characteristic – when deployed in a given camera system – in a manner that provides the best combination of camera output Luma sensitivity, dynamic range, and signal noise. This must take into account the spectral power distribution associated with the scene illumination, and the lens transmission (which has its own spectral response) – the combination affecting the illumination projected onto the image sensor. In the camera, the spectral sensitivity functions of the color filter array (CFA) on the front of the CMOS sensor coupled with the spectral sensitivity of the image sensor itself also affect the levels of RGB information encoded in the sensor output signal. This combination, in turn, will dictate unpredictable levels of video amplification in the video processing system following the image sensor.

The final output Luma video signal is made up of proportions of the three RGB signals and will be subject to their respective noise levels in the dark scene areas and their separate image sensor clipping levels in the highlight areas. The task becomes one of anchoring or mapping a point on the image sensor linear transfer characteristic that defines a reference exposure point that will help ensure optimization of the overall camera operational performance. The native sensitivity rating of the camera will be defined by the selection of this reference point. The dynamic range of the camera will be defined by the number of stops of latitude above and below that reference point. Rationalizing all of these variables is what differentiates the camera system design approaches of the different camera manufacturers.

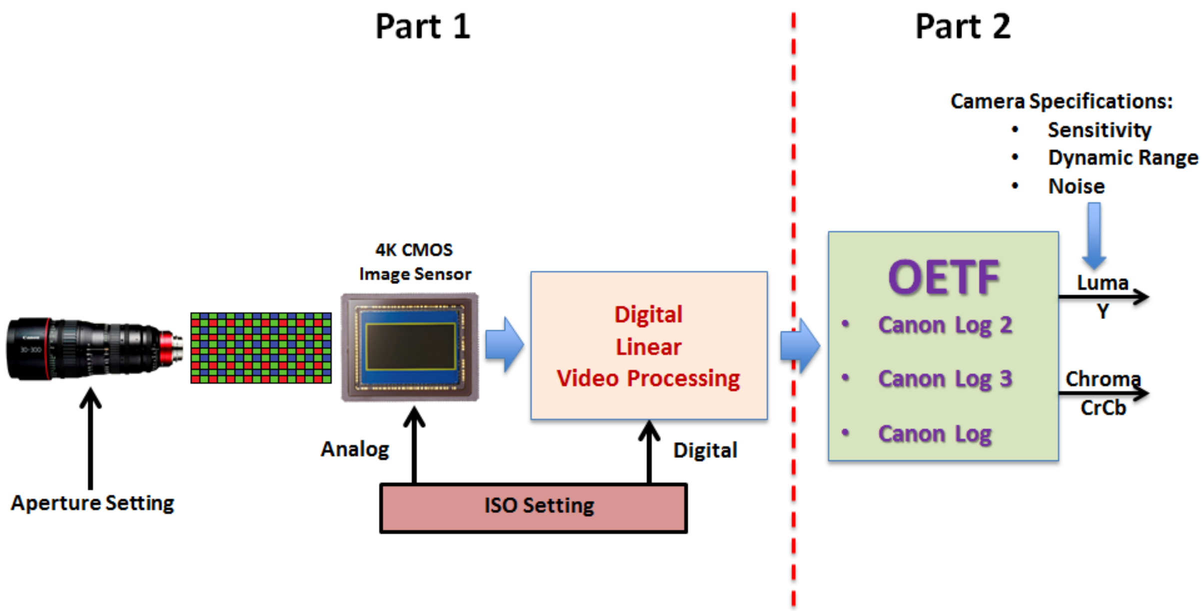

Figure 3 *Showing the components either side of the image sensor that significantly influence how its dynamic range characteristic is mapped to produce the final camera specifications*

The camera system can be separated into two parts as indicated in Figure 3. Part 1 is the linear section where the linear light representation delivered by the image sensor is sent to a video processing system. Part 2 is the nonlinear section that entails the Opto Electronic Transfer Function (OETF) that prepares the digital signal in a manner helping to ensure that all of the HDR information can be both faithfully recorded and be transmitted via standardized interfaces to an external system. This paper will look closely at Part 1 and the implications of HDR on video signal levels. A companion white paper will examine Part 2.

3.0 THE IMAGE SENSOR

3.1 Dual Pixel CMOS Image Sensor – having 15-Stop Dynamic Range

Among numerous design strategies in the Super 35m CMOS image sensor developed for the EOS C300 camera was an innovative new photosite design that employed two separate photodiodes – each being 6.4 x 3.2 micrometers.

The EOS C700 and EOS C300 Mark II both employ a Super 35mm CMOS sensor which is based on the same dual photodiode per photosite [4]. Additional innovations within the photodiode design in combination with new on-chip noise cancellation technology have simultaneously elevated the saturation level of the charge well and further lowered the noise floor. In addition, this microlens design heightens the efficiency of light direction onto the two individual photodiodes while also improving the separation between the two photodiode outputs (this being especially important to the secondary role of the two photodiodes in their implementation of the Dual Pixel CMOS Auto Focus function) [3]. For simplicity this novel design is referred to as the Dual Pixel CMOS image sensor and the basic concept is illustrated in Figure 4. The photosite dimensions are shown in Figure 5.

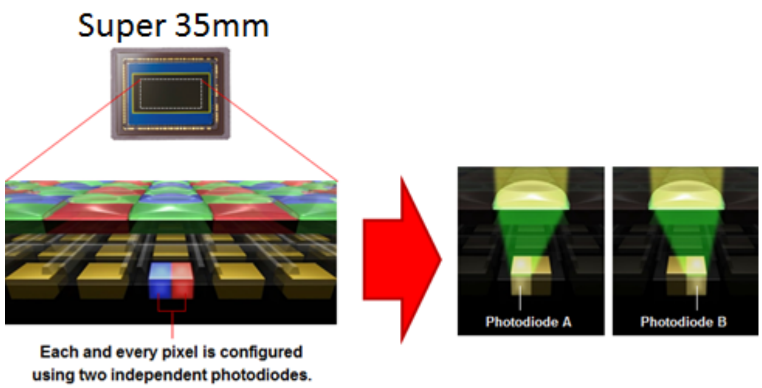

Figure 4 *A representation of the dual pixel CMOS image sensor with a specially designed microlens that optimizes the focusing of the incident light onto both photodiodes*

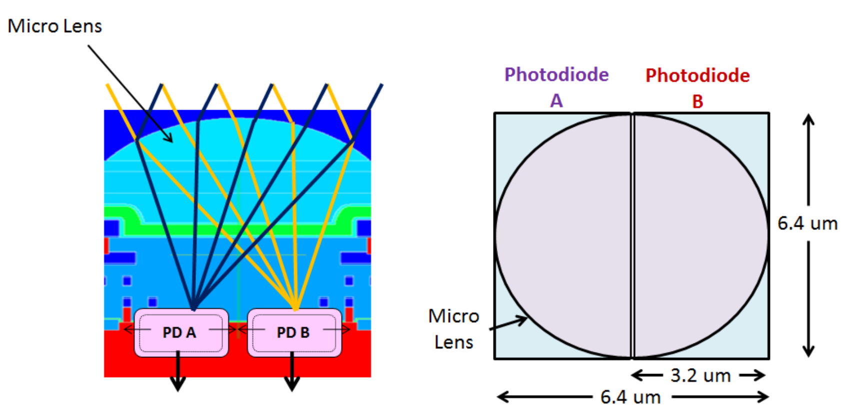

Figure 5 *Showing the dual photodiode and microlens structure within a single photosite in the 4K CMOS image sensor used in the Cinema EOS cameras*

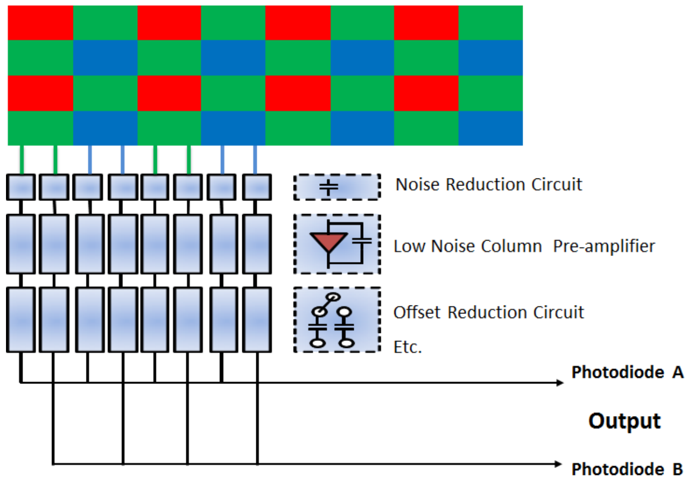

Figure 6 *Showing the principle of the dual output from each individual photosite and the unique column readout circuits employed within the image sensor itself*

The combination of these design strategies contribute to a 3-stop increase in effective photosite dynamic range compared to the image sensor in the original EOS C300 camera. This provides a *15-Stop* dynamic range capability in the EOS C700 cinematography camera.

3.2 Image Sensor Dynamic Range

Figure 7 shows the linear light representation of the CMOS image sensor deployed in the EOS C700 and EOS C300 Mark II cameras. This is bounded at the upper end by the saturation of the photodiodes under high light inputs and at the lower end by the image sensor noise floor.

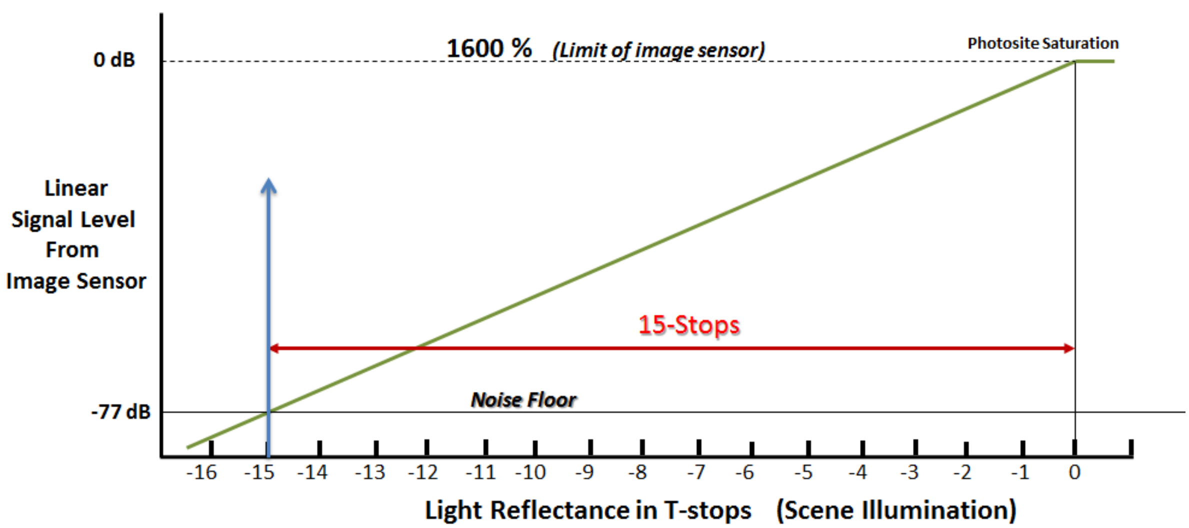

Figure 7 *Showing the 15-Stop linear light transfer characteristic of the CMOS image sensor in the EOS C700 and EOS C300 Mark II cameras*

3.3 Image Sensor Signal to Noise

Canon developed a diversity of strategies to help control the level of noise in the final video signal delivered at the CMOS image sensor output. They are summarized in Figure 8.

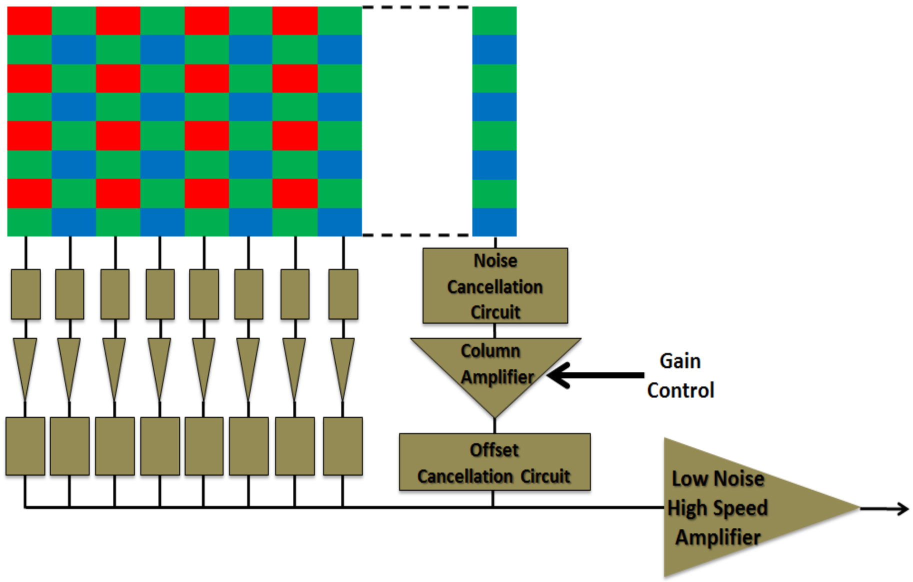

Figure 8 *Highlighting the column structure for reading out the signal from the CMOS image sensor*

The readout architecture inherent to CMOS images entails column readout circuits. Canon's embodiment of that readout circuit uses a unique noise cancellation circuit followed by a low-noise column amplifier. Because the signal content being handled in each column is extremely limited the bandwidth of that amplifier is exceedingly low. If the gain of that column amplifier is increased the signal output will increase proportionally but the associated noise will increase only very slightly. As the column amplifier gain is raised the footprint of the noise sources *following that amplifier* – that include the thermal noise of the wideband final output amplifier, reset noise, and finally, the quantization noise of the ADC – is effectively reduced thus providing a net gain in signal to noise ratio .

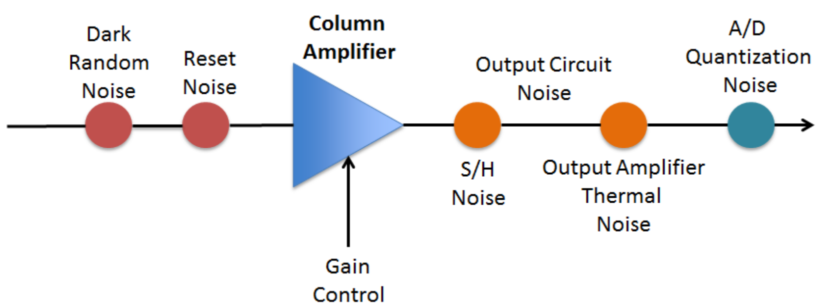

Figure 9 *The various noise sources within the CMOS image sensor system*

When scene illumination is in line with lower camera exposure settings (ISO 100 – 800) the column amplifier has a gain of 0.5 times. At these exposures, for a peak signal output the image sensor delivers in excess of 80,000 electrons and the noise floor is approximately 11 electrons – as shown in Figure 10

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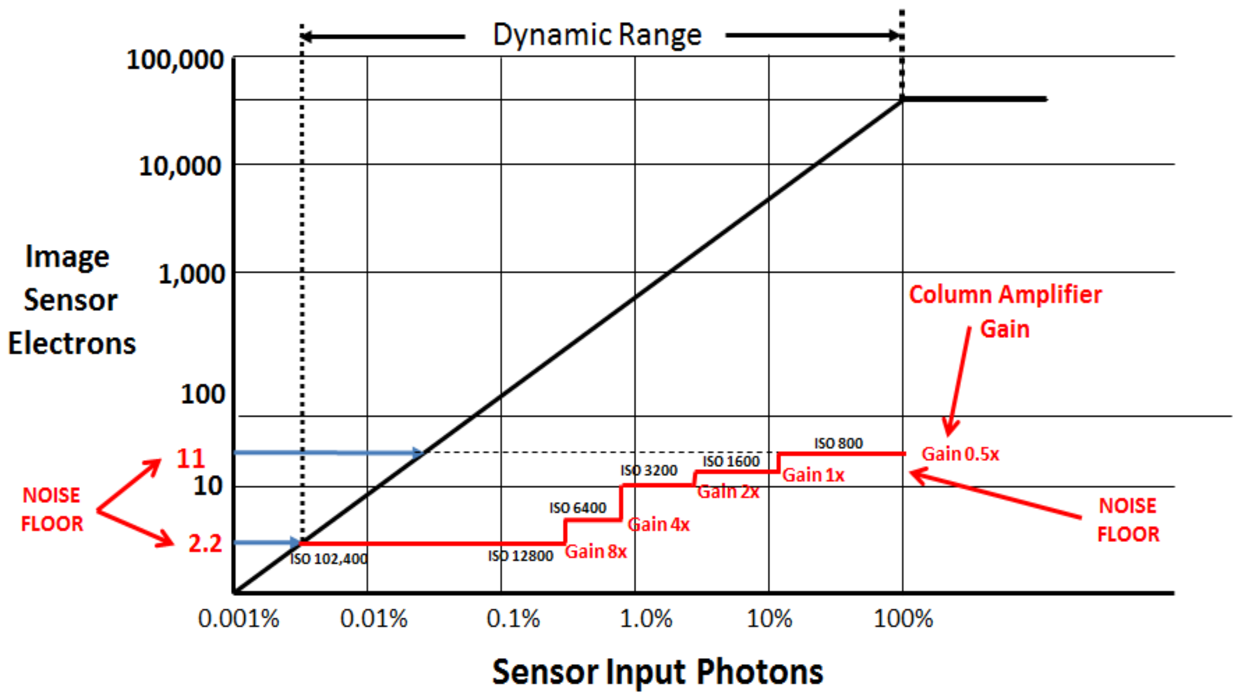

Figure 10 *Increasing the amplification of the column amplifier progressively lowers the overall noise floor of the image sensor*

Elevating the camera ISO settings to compensate for lowering scene illumination entails a progressive increase of the column amplifier gain in the manner shown in Figure 10. The overall behavior of noise in the CMOS image sensor across the range of ISO settings is shown in Figure 11. It is a quite nonlinear characteristic because of the progressive elevation of column amplifier gain effectively depressing the noise floor. At ISO 6400 the Luma signal to noise ratio has degraded by a mere 2dB.

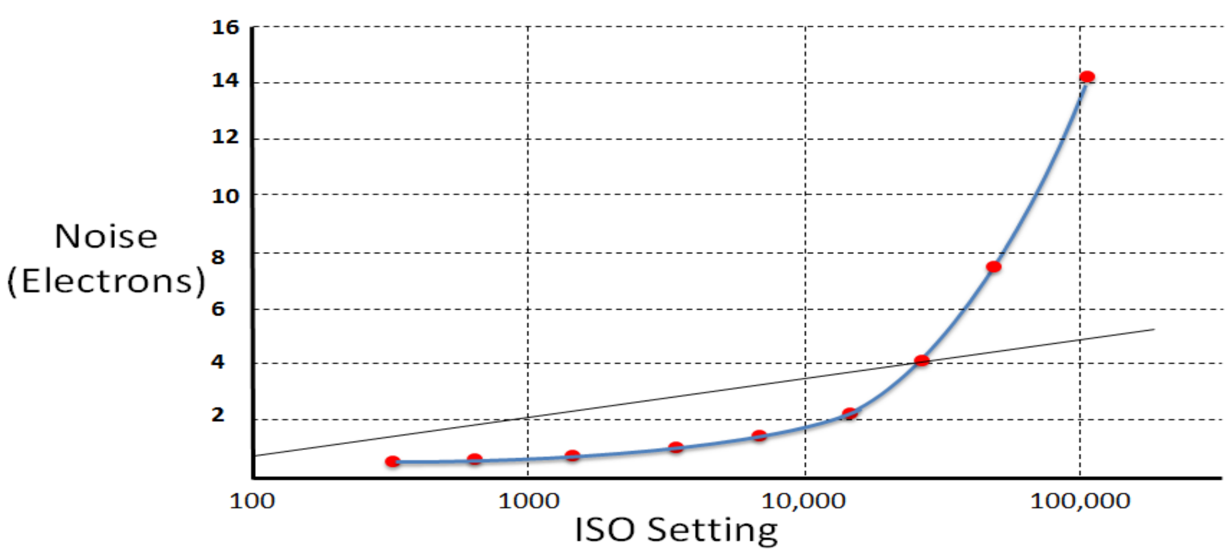

Figure 11 *The behavior of EOS C300 Mark II image sensor noise over the range of ISO settings*

4.0 THE CAMERA SYSTEM

4.1 Camera Dynamic Range and Reference Exposure

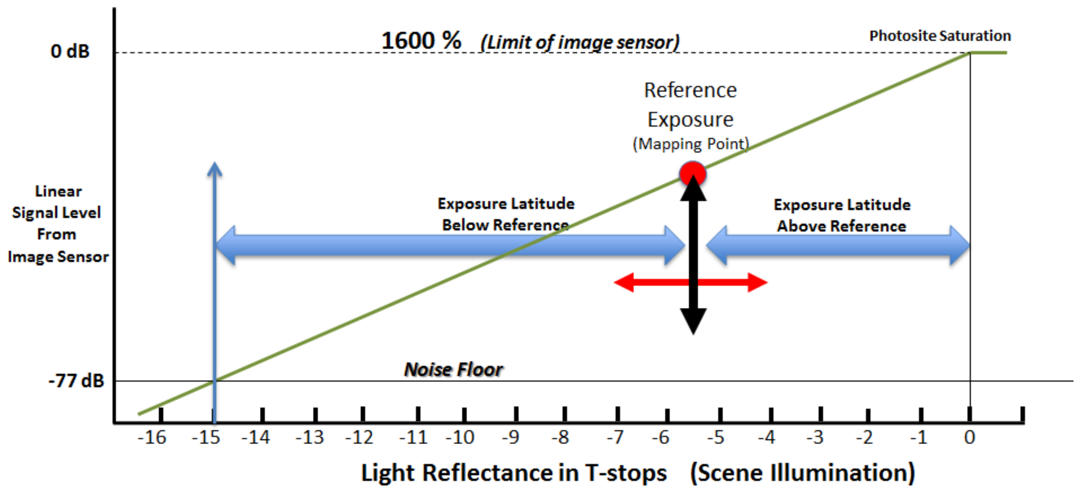

Figure 12 *Illustrating the concept of the search for a mapping point for the camera deploying the CMOS image sensor shown in Figure 7*

Over many decades the television broadcast industry has successfully deployed a methodology of specifying the sensitivity of their lens-camera systems. The motion picture film industry had a quite different approach and this has carried over into the contemporary digital cine cameras. Both approaches will be examined in the context of the EOS C700 and EOS C300 Mark II cameras. This examination will focus initially on the linear signal output from the image sensor. The application of the all-important camera Opto Electronic Transfer Function (OETF) will be examined in a second paper.

4.2 Traditional Video Assessment of Dynamic Range

As contemporary digital cameras continue to extend their dynamic range it is useful to do an initial assessment of camera Dynamic Range using traditional video techniques. This offers the advantage of harnessing long-established thinking with respect to video signal levels. This, in turn, helps to better visualize the relevance of the dynamic range specification of a particular image sensor to final video representation.

In traditional video terms the reference “anchor” is the 89.9% reflectance white chip (found on most gray scale charts). With the camera operating at a specified frame rate, and Master Gain set to 0dB, the test chart is illuminated by 2000 Lux of 3200 degree Kelvin lighting, and the lens aperture is adjusted to produce the familiar 100% Luma video level on the waveform monitor (equivalent to 700 mVolts peak in terms of analog Luma signal). That lens setting is then quoted as the camera system sensitivity and that sensitivity specification is considered complete when this is accompanied by the measured Luma signal to noise ratio.

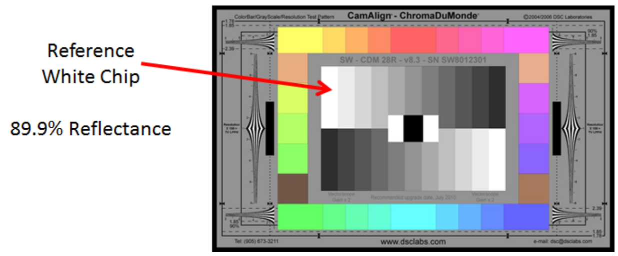

Figure 13 *Showing a typical video test chart with the 89.9% reflectance white chip*

Knowing all of the image sensor technical performance parameters, the video camera system has traditionally had its nominal *system gain setting* – with the operational Master Gain control set to 0 dB – chosen by the design engineers based upon three criteria:

1. Achieving a desired camera output Luma Signal to Noise specification at that Master Gain setting
2. Achieving a desired Tonal Reproduction – that is, a specified contrast ratio at nominal camera exposure
3. Allowing Sufficient image sensor overhead to handle a specified degree of highlight over-exposure

Over most of the history of broadcast television cameras a priority was given to achieving as high as possible Luma S/N and contrast ratio specifications. As a consequence dynamic range was generally curtailed. This practice underlays the development of the HDTV production standard ITU-R BT.709.

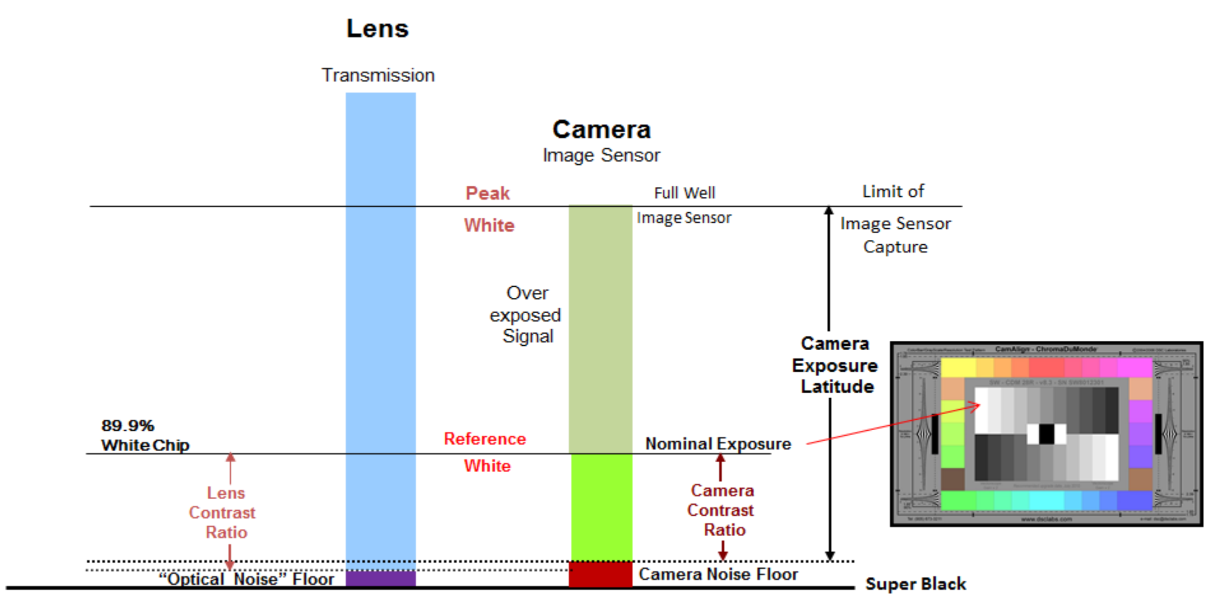

Figure 14 *Traditional video exposure practices where the 89.9% reflectance chip on the gray scale chart is set by the lens aperture to produce 100 IRE level of Luma on a video waveform monitor*

If the EOS C700 camera system is set up to originate traditional HDTV video according to the BT.709 standard then the following represents criteria to appropriately select a Mapping Point:

1. Sufficient exposure latitude below the 100% reference to help ensure a high tonal reproduction for nominally exposed scenes and an ability to reproduce colored details in unusually dark areas of the scene

2. A high Luma signal to noise ratio at the 100% reference level – of at least 65 dB

3. Acceptable exposure latitude above the 100% reference white that will satisfactorily reproduce a modest level of scene overexposure

4. Given the severe limitation of the standardized BT.709 OETF not much more than 2-Stops above reference white (for the linear signal) can be considered practical – and even here the camera designers endeavor to extend this with their traditional "knee and slope" strategies

Figure 15 summarizes the mapping on the linear representation of the camera dynamic range that meets all of these criteria.

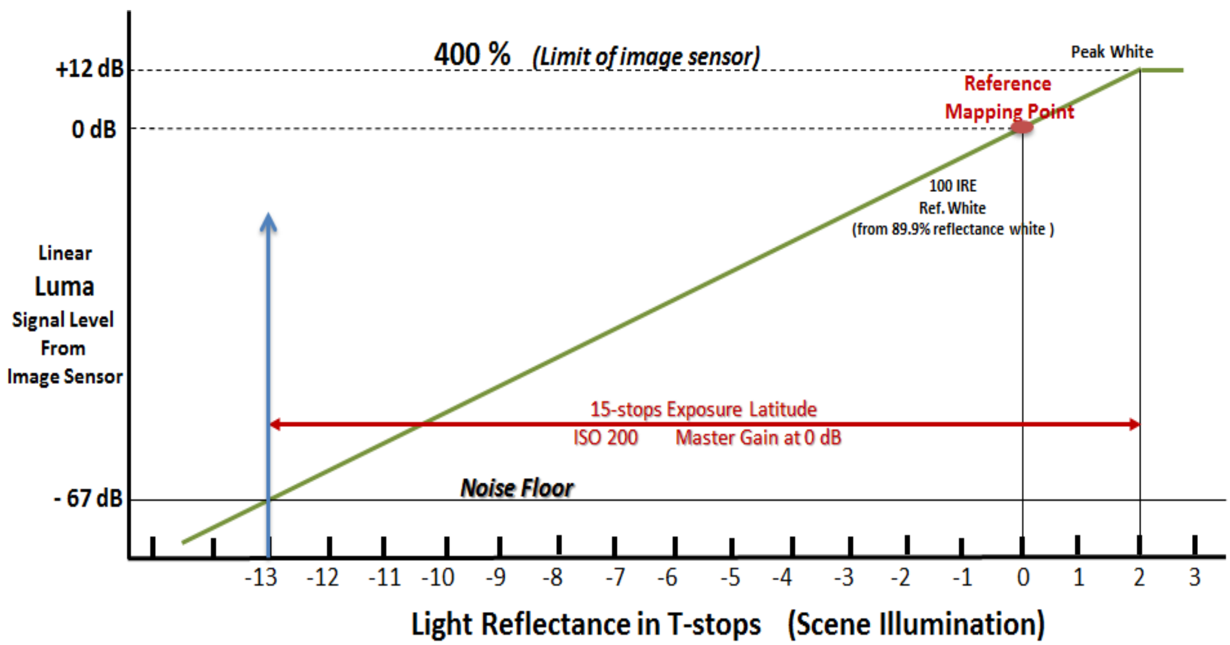

Figure 15 *Showing the mapping that was decided upon for the EOS C700 and EOS C300 Mark II cameras on the linear light representation when set to originate HDTV video according to the ITU-R BT.709 production standard*

4.3 Deep Dive into Video Signal Levels

It is useful to chart the dynamic range of the camera linear representation in specific video Luma signal levels associated with each of the 15-Stops of dynamic range – as shown in Table 1. This indicates the video levels in both percentage and in millivolts (using as a reference the traditional analog 700 mVolts for the Luma 100% white level).

Signal Level (mVolt)	Signal level (Percent)	T-Stop	
2800	400	+2	Peak White (400 %) (360 % reflectance)
1400	200	+1	
700	100	0	Reference White (89.9 % Reflectance)
350	50	-1	
175	25	-2	
87.5	12.5	-3	
43.75	6.25	-4	
21.88	3.13	-5	
10.94	1.56	-6	
5.47	0.78	-7	
2.74	0.39	-8	
1.37	0.20	-9	
0.64	0.10	-10	
0.32	0.05	-11	Lower boundary defined by Luma S/N of 68 dB
0.16	0.025	-12	
0.08	0.0125	-13	

Table 1 *Showing the linear light representation of the EOS C700 and EOS C300 Mark II cameras when set for BT.709 mode – using the traditional 700 mV Luma level (or 100 Percent on the waveform monitor) for reference white*

This chart shows that the upper limit (peak white) corresponds to 400 % or 2,800 mVolts. At the lower extremity, the chart also shows that the linear change in signal level associated with that last lower stop is a mere 0.0125 % – or 0.08 mV peak. The specified Luma signal to noise ratio for the C700 is 68 dB – which translates into 0.28mV rms level of noise. This noise level is fractionally lower than the peak to peak lowest discrimination on video level at the minus 11-stop setting. But that noise level is considerably higher than the video levels corresponding to both the -12 and -13 stops

The definition of the lower limit of sensor dynamic range [5] is when the signal to noise ratio of the lowest discriminatory step is unity – or 0 dB – Figure 16. Thus, the *effective* dynamic range for the camera linear signal that is being prepped to operate in the BT.709 mode is 13-Stops (from + 2-stops to -11.0 stops with respect to reference white).

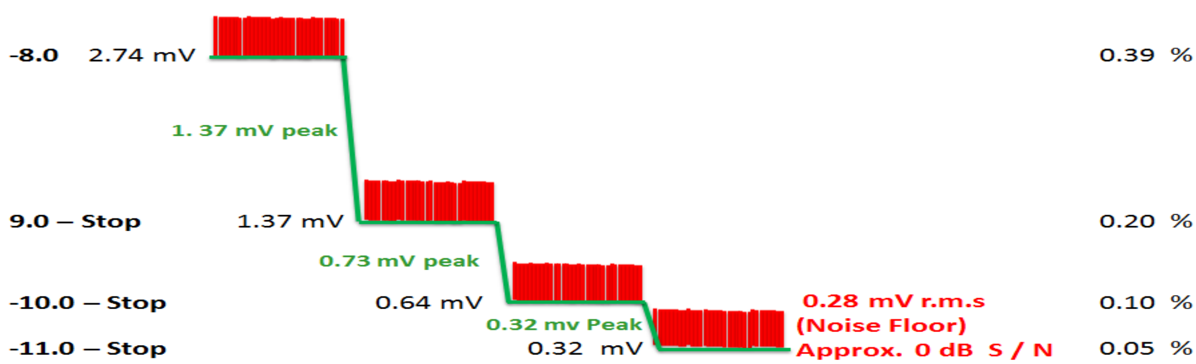

Figure 16 *Illustrating the lower video signal levels (in millivolts) and the rms noise associated with the camera Luma specification of 68 dB that define the lower boundary to effective camera dynamic range*

4.4 Overcoming the Dynamic Range Limitations of BT.709

Clearly, the traditional setting of BT.709 as described does not do justice to the HDR capabilities that are latent within the 15-stop dynamic range of the image sensor. A different re-mapping of the camera settings are required to fully exploit this 15-stop DR. In addition, the subsequent OETF specified by BT.709 must also be replaced with a form of logarithmic OETF to help ensure preservation of the full 15-stop range – this will be discussed in a separate paper.

Fortunately, the very high signal to noise performance of the image sensor system in these cameras does allow such re-mapping. By setting the Master Gain to +12 dB and readjusting the lens aperture to restore 100% Luma, the reference white mapping point on the linear transfer characteristic of the EOS C700 and EOS C300 Mark II cameras is altered to that shown in Figure 17. Table 2 shows that the full 15-stops are now available for the OETF. The 0dB signal to noise limitation is reached at -11-stops.

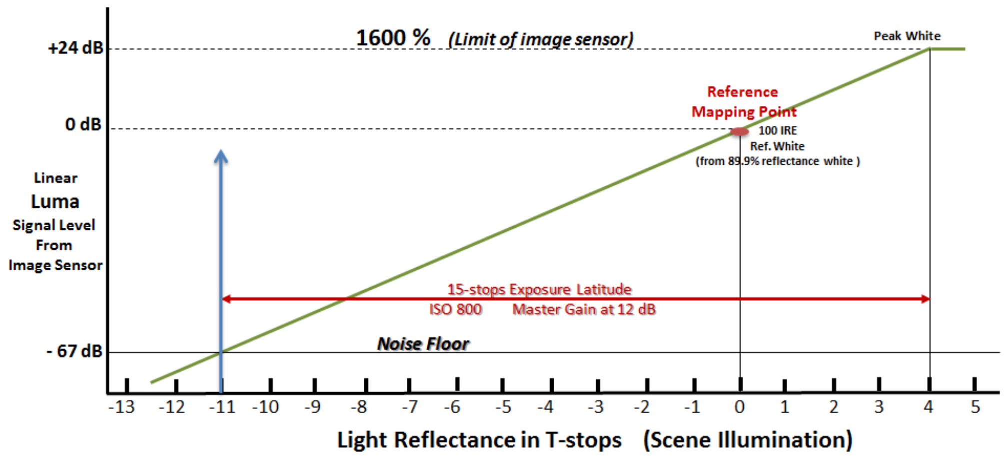

Figure 17 *The readjusted camera system mapping of the reference white setting (with Master Gain now set at +12 dB) produces the linear light transfer characteristic as shown*

Signal Level (mVolt)	Signal level (Percent)	T-Stop	
11200	1600	+4	Peak White (1600 %) (1440 % reflectance)
5600	800	+3	
2800	400	+2	
1400	200	+1	
700	100	0	Reference White (89.9 % Reflectance)
350	50	-1	
175	25	-2	
87.5	12.5	-3	
43.75	6.25	-4	
21.88	3.13	-5	
10.94	1.56	-6	
5.47	0.78	-7	
2.74	0.39	-8	
1.37	0.20	-9	
0.64	0.10	-10	
0.32	0.05	-11	

Table 2 *Showing the 15-Stop linear light mapping of the EOS C700 and EOS C300 Mark II camera systems*

4.5 The Cinematography Perspective

In cinematography, the camera operational sensitivity is measured as an Exposure Index (EI) – formerly quoted as an ASA speed, but today more usually expressed as an ISO speed. The established practice within the motion picture film community (and increasingly with digital cine) is to measure the ISO value using a light meter and a neutral gray card of 18% reflectance and set the exposure to produce 20% Luma video level (prior to application of the camera OETF).

Figure 18 *The cinematographer uses a light meter and an 18% gray chart to set camera exposure*

4.6 Deep Dive into Cinematography Dynamic Range Signal Levels

Using the reference 18% gray as the cinematography mapping point will produce the range of Luma signal levels (in both percent and millivolts) – as shown in Figure 19. The EOS C700 and EOS C300 Mark II image sensors extend dynamic range at *both extremities* compared to that of the original EOS C300 camera.

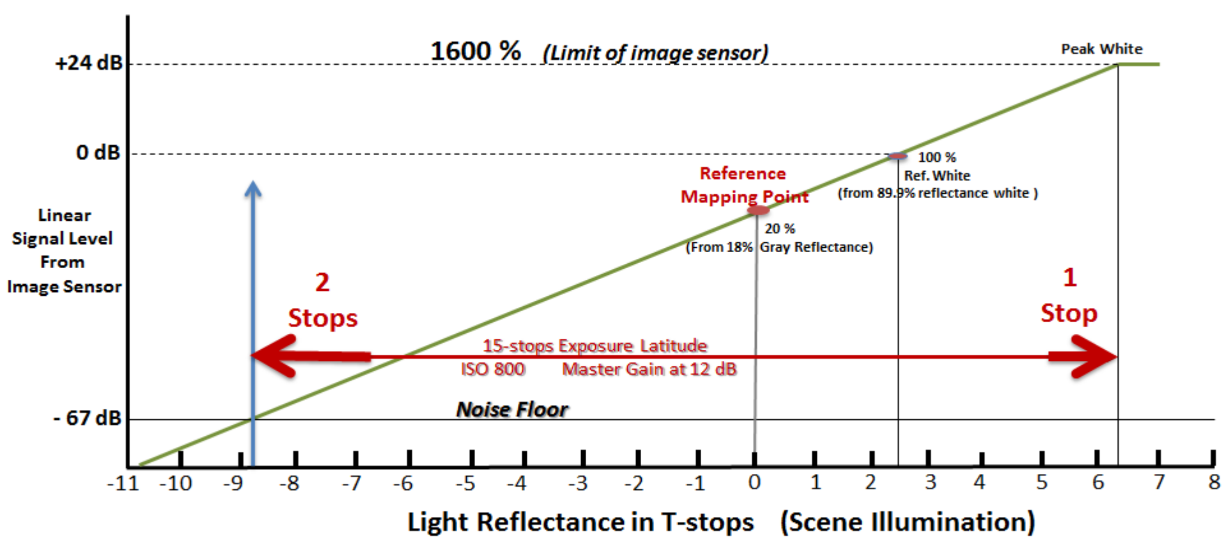

Figure 19 *The linear light representation of the S35mm CMOS image sensor with the two arrows indicating the extension of its dynamic range beyond the 12-stop range of the original EOS C300 cine camera*

The base sensitivity of this camera has been set at ISO 800 (Master Gain setting of +12 dB). There is a recognized method of calculating the reference ISO speed rating of the digital cine camera that corresponds to the television sensitivity specification [6].

If the associated lens has a hypothetical reference stop that is set to zero for this 18% reflectance gray reference exposure then the linear behavior of the image sensor can be examined by progressively opening up the lens aperture to examine the upper limit on highlights, and stopping down the lens to examine the lower limit in deep shadows as shown in Table 3.

Signal Level (mVolt)	Video Signal level (Percent)		T-Stop	
	2560		7	
		1600		+6.3 Peak White (1600 %) from 1440 % reflectance
	1280		6	
	640		5	
	320		4	
1120	160		3	
		100		
560	80		2	
280	40		1	
140	20		0	Reference Gray (18 % Reflectance)
70	10.0		-1	
35	5.0		-2	
17.5	2.5		-3	
8.75	1.25		-4	
4.38	0.63		-5	
2.19	0.32		-6	
1.09	0.16		-7	
0.55	0.08		-8	
0.35		0.05		-8.7
0.27	0.04		-9	

Table 3 *Showing the behavior of the exposure latitude of the EOS C700 camera above and below the reference exposure on an 18% gray card*

The noise floor of 0.28mV r.m.s is reached at close to 9.0-stops below the 18% reference gray reflectance and the peak white capability of the image sensor translates into +6.3-Stops above the reference 18% gray exposure.

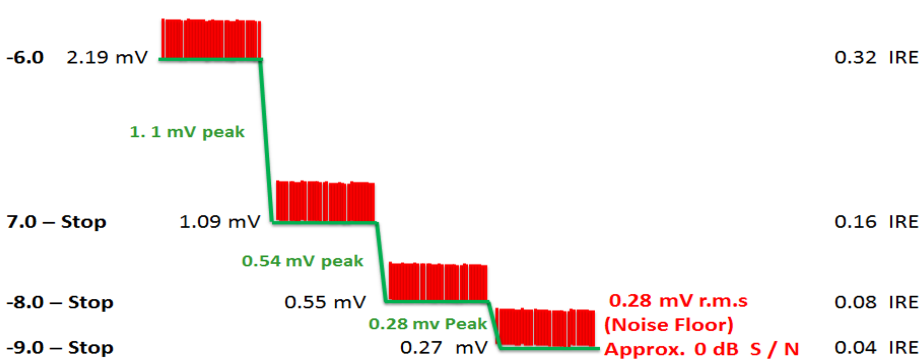

Figure 20 *Illustrating the lower video signal levels (in millivolts) and the rms noise associated with the camera Luma specification of 68 dB that define the lower boundary to effective camera dynamic range*

As can be seen from Table 3 the last two of the 15-stop range are associated with video signal levels of a fraction of a millivolt (when 100% reference white is equivalent to 700 mV Luma). It is hard to visualize such signal levels being associated with meaningful real world imagery.

But, to the creative community such low levels of image detail can actually mean a great deal. In many feature films, television episodics and dramas, deep shadowed scenes are carefully structured and appropriately lit to create particular “moods” desired by the director. Within those dark areas there can be a myriad of subtle details and textures whose visibility are integral to the storytelling. It was for this reason that Canon gave a special priority to extending the dynamic range of the new CMOS image sensor a full two stops further down than the capability of the EOS C300 image sensor.

Some examples of such scenes are shown in Figure 20.

Figure 21 *Two typical scenes containing both highlights and dark regions within the same scene – with HDR offering the possibility of portraying the details contained in both*

The scene on the upper left would significantly benefit from HDR image capture. The extended latitude below the reference 18% gray would help ensure capture of the extremely subtle low level details within the dark portions of the scene – especially faces, hair, and their clothing textures – while the extended latitude above the 18% gray can help ensure improved capture of the reflected store fronts in the car windows.

A scene as typified by that on the lower right in Figure 20 presents even greater challenges in faithfully reproducing the details in the background windows while also allowing recovery of the myriad of details in the dancer’s faces and legs as well as the textural details of their clothing and of the flooring. With the astounding prowess of today’s postproduction signal recovery and noise reduction processing all of the many details in that dimly lit kitchen can be readily reproduced. This particular scene might possibly benefit from a lower exposure as the highlights are modest – for example an exposure set to ISO 200 would afford greater latitude below the reference 18% gray.

Video Signal level (Percent)	T-Stop		
640	5		
320	4		
160	3		
80	2		
40	1		
20		0	Reference Gray
10.0	-1		(18 % Reflectance)
5.0	-2		
2.5	-3		
1.25	-4		
0.63	-5		
0..32	-6		
0.16	-7		
0.08	-8		
0.04	-9		
0.02	-10		
0.01	-11		

Table 4 *Showing the extended exposure latitude below the 18% gray reference if the camera is set to ISO 200 (Master Gain at 0 dB)*

5.0 RELEVANCE TO HDR CONSUMER DISPLAY SPECIFICATIONS

In January 2016 the Ultra HD Alliance (UHDA) comprised of 35 member companies [7] published their specifications for UHD, along with a logo identifying devices approved for displaying Ultra HD content that meet these specifications. Of particular note are the HDR specifications for the two principal consumer display technologies – namely, OLED and LCD – shown in Table 5. These specifications reflect the still modest – but impressive – highlight levels of luminance of contemporary HDR consumer displays. But, they also reflect the recognition that these displays are capable of portraying very deep black levels – 0.05 nits for the LCD and 0.0005 nits for the OLED.

TABLE 5

	Content	Distribution	Consumer Display
Resolution	3840 x 2160	3840 x 2160	3840 x 2160
Bit Depth	10-Bit	10-Bit	10-Bit
Color Palette	BT.2020	BT.2020	Signal Input: BT.2020 Display: > DCI P3
HDR			
EOTF	ST2084	ST2084	ST2084
Mastering Display	> 1000 nits (Peak) < 0.03 nits (Black) > DCI P3		LCD: > 1000 nits (Peak) < 0.05 nits (Black) OLED: > 540 nits (Peak) < 0.0005 nits (Black)

It is noteworthy to align the HDR imaging capabilities of the EOS C700 and EOS C300 Mark II cameras with these display HDR specifications – as shown in Table 6. On the left is shown the range of luminance levels that are specified by the UHDA specification – and aligned with this, on the right is the linear light level range of the EOS C700 and EOS C300 Mark II cameras. This assumes that the displays use the traditional television reference of 100 IRE reference white being portrayed at approximately 100 nits.

Display Luminance (Nits) ULTRA HD PREMIUM LCD	Display Luminance (Nits) OLED	Signal level (Percent)	T-Stop	
		1600	+4	Peak White (1600 %) (1440 % reflectance)
1000				
800		800	+3	
	540			
400	400	400	+2	
200	200	200	+1	
100	100	100	0	Reference White (89.9 % Reflectance)
50	50	50	-1	
25	25	25	-2	
12.5	12.5	12.5	-3	
6.25	6.25	6.25	-4	
3.13	3.13	3.13	-5	
1.56	1.56	1.56	-6	
0.78	0.78	0.78	-7	
0.39	0.39	0.39	-8	
0.20	0.20	0.20	-9	
0.10	0.10	0.10	-10	
0.05	0.05	0.05	-11	
	0.0005			

Table 6 *Showing that the 15-stop dynamic range of the EOS C700 and EOS C300 Mark II cameras align almost perfectly with the specifications for an LCD HDR display while not quite doing so for the black level of the OLED*

It can be seen that the first generation of HDR consumer displays anticipate that HDR will entail reproduction of details within deep black regions of many scenes.

6.0 SUMMARY

This paper examined the performance level achieved in the Canon-developed Super 35mm 4.5K CMOS image sensor and the advances made in controlling the noise floor and extending the dynamic range. Given the 15-stop dynamic range, the task of mapping an optimal operating point within the overall camera system (that includes the lens) for this image sensor was looked at from the point of view of traditional television perspectives as well as that of the digital cinema perspective.

The paper focused on the linear representation of the image sensor video output. Most can relate to the analog representations seen on video waveform monitors and the 700mV peak that has long represented 100% reference white level. With that in mind, special attention centered on the implications of the 15-stop dynamic range on the exceptionally low video signal levels encountered and the noise levels associated with them. These signal levels can be as important to certain dark scenes as are the enhanced exposure range in highlights that are offered by HDR imaging. They can contain essential textural detail that the production team deem important to some scenes. This is seen increasingly in contemporary television episodics since wide dynamic range cameras became the norm. While recovering such low level details might appear daunting it must be recognized that contemporary color grading systems have advanced to a level where this is readily achievable. Of particular note is the fact that the UHD Alliance has recognized that HDR in the new generation of HDR consumer displays is all about significant expansion of portrayed contrast – with attention to simultaneous extensions into the deep blacks as well as the highlights.

With a better understanding of what an HDR camera can deliver at both extremities of the exposure range the companion white paper – Deep Dive Part 2 that deals with the choice of camera OETFs available in the EOS C700 and EOS C300 Mark II – will hopefully be better understood.

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