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CINEMA EOS

EXTENDED RECORDING CAPABILITIES IN THE EOS C700 CAMERA

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Abstract

The original EOS C300 camera was introduced in November 2011. It uses a 4K single image sensor to exclusively originate the 1920 x 1080 HD production format [1]. It records this on-board using an MPEG-2 codec operating 8-bit YCrCb 4:2:2 @ 50 Mbps. The EOS C500 Camera followed in 2012 and supported external 4K RAW recording. The EOS C100 Mark II was introduced in the latter half of 2014 and the EOS C300 Mark II was unveiled at NAB 2015.

The successor C300 Mark II camera [2] [3] offers significantly elevated video performance and expanded operational capabilities. Unlike its predecessor, the EOS C300 Mark II Camera offers a choice of 4K / UHD / 2K / HD origination and greatly extended on-board recording capabilities by deploying a new codec based upon the more advanced MPEG-4 H.264 Advanced Video Coding (AVC) compression algorithm. In addition, the C300 Mark II offers a choice of 4K or UHD origination and recording using the XF-AVC codec [4] at a very high bit rate at frame rates up to 29.97 fps progressive. Finally, the camcorder offers alternative uncompressed 10-bit 4K RAW or 2K / HD component video outputs via a 3G-SDI terminal for external recording.

November 2016 – the fifth anniversary of the debut of the Cinema EOS system is witness to the debut of the first A-Camera from Canon – the EOS C700. The accumulated worldwide experiences with the C300 / C500 / C300 Mark II cameras and the ongoing dialog with the production communities of both television episodics and theatrical motion pictures contributed to the development of this fully fledged camera. The EOS C700 broadens the on-board recording options for all of the production formats. It also has a dockable recorder that can record 4K RAW at 12-bit at frame rates up to 60 fps and at 10-bit up to 120 fps. Unlike the other Cinema EOS cameras that RAW signal has no baked-in video processing other than a unique new OETF that enhances the capture of all of the impressive HDR details originated by the camera.

1.0 INTRODUCTION TO EOS C700 CAMERA

The central goal of the EOS C700 is to harness developments in the Super 35mm image sensor and associated video processing to further refine HDR and WCG digital motion imaging capabilities. At the same time, the increasing adoption of 4K / UHD for high-end program origination spurred a significant expansion to their associated recording options in this camera. Accordingly, the EOS C700 design placed a priority on five key advances beyond the EOS C300 Mark II:

1. ***RAW Recording*** -- uncompressed 4K / UHD @ 12-bit up to 60fps and at 10-bit up to 120 fps – in a dockable recorder

2. ***On-board Recording*** – choice of either an XF-AVC codec or ProRes codec

3. ***On board Recording*** – of 4K and UHD – now extended up to 60 fps

4. ***On-board Recording*** – of 1080-line HD and the 2K digital cine format – up to 120 fps

5. ***On-board Recording*** – of a cropped 2K / HD – up to 240 fps

2.0 OVERVIEW OF THE RECORDING OPTIONS IN THE C700

The C700 differs from the companion C300 Mark II in five key respects:

1. In addition to the same XF-AVC codec [4] deployed in the C300 Mark II for on-board recording of 4K / UHD / 2K / HD the C700 offers an additional option of the ProRes codec [5]. Both codecs record to two CFast 2.0 memory cards

2. 4K RAW signal output is prepared in a quite different manner to that of the C500 and C300 Mark II. Operational settings of digital white balance control, and color gamut selection are not baked-in – but are instead added as metadata to the 4K RAW signal to facilitate their implementation downstream within the Canon Cinema RAW Developments software

3. While the on-board compressed recordings entail a choice of the same three Canon Log functions [6] as the C300 Mark II – the 4K RAW has a different OETF applied that has been optimized for that particular signal

4. The 4K RAW signal is recorded in a specially designed dockable recorder – see Figure 1

5. That same dockable recorder can also record Apple ProRes as shown in Figure 1

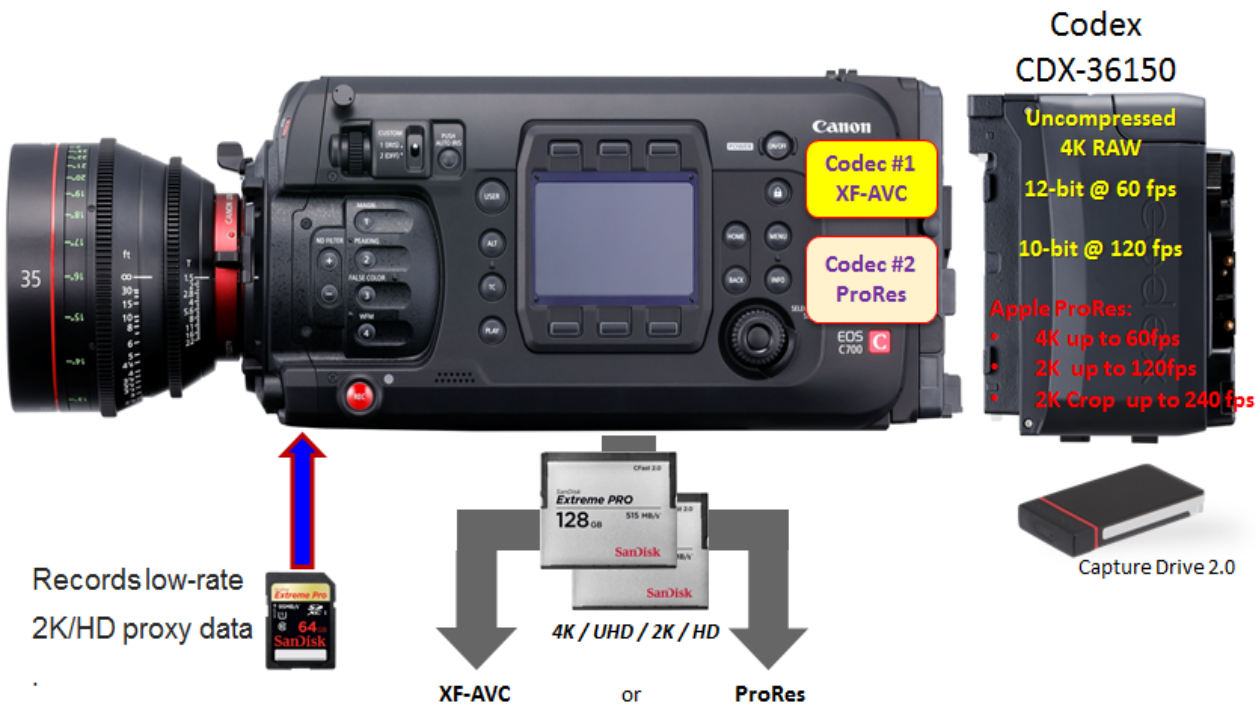

Figure 1 *The C700 offers three distinct options for recording – a choice between two on-board codecs with additional RAW recording capability to a dockable Codex recorder*

The EOS C700 has an extended sensitivity range – from ISO 100 up to ISO 102,400. This control is shared between an analog control (controlling the gain of the column amplifier within the CMOS image sensor [7]) and a downstream digital control. In the case of the on-board recorded signals both controls are used. For the 4K RAW signal the analog control within the image sensor is progressively stepped up from ISO 800 to ISO 25,600 – with the separate digital settings sent as metadata that implements this control in postproduction.

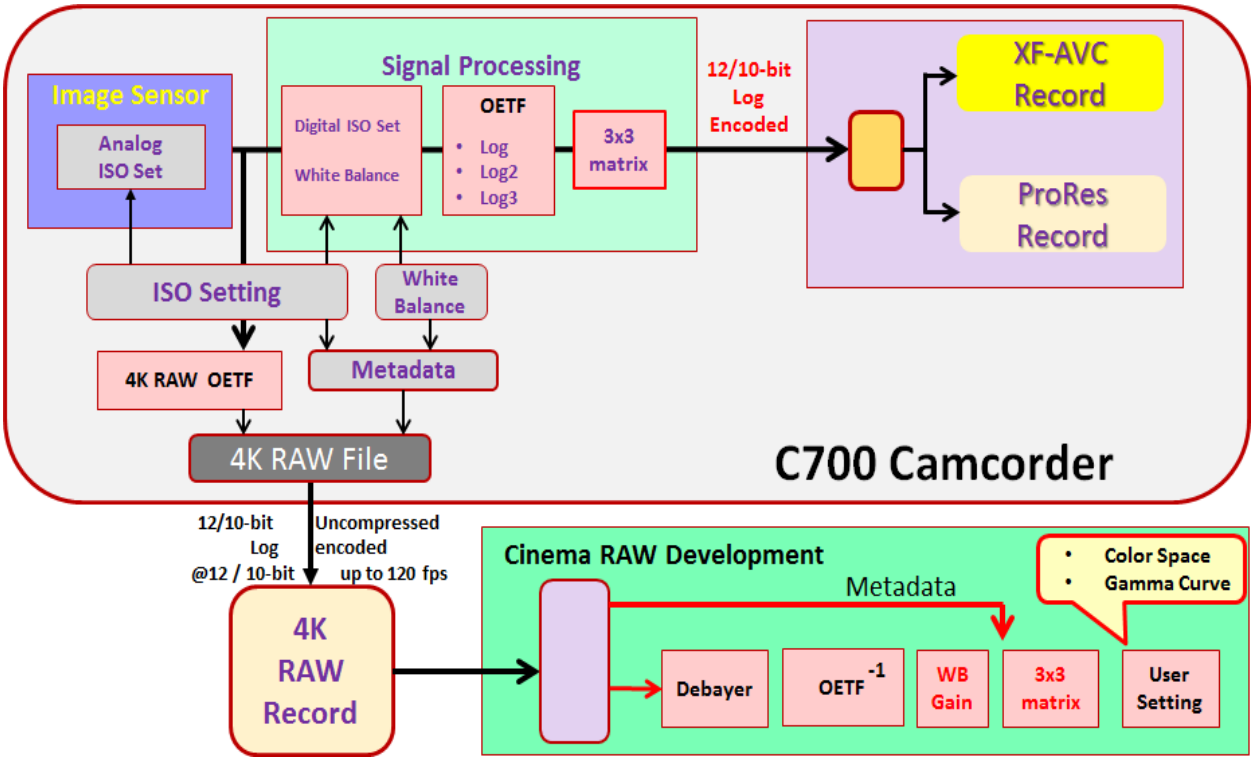

Figure 2 *The EOS C700 offers a choice of two on-board recording codecs – the Canon XF-AVC and the Apple ProRes – in addition to external uncompressed 4K / UHD RAW recording in a dockable recorder*

3.0 4K / UHD RAW RECORDING

Canon partnered with Codex and their engineering teams to create a high performance integrated RAW recording solution for the Cinema EOS C700 camera in the form of a directly dockable compact recorder [8]. The 4K RAW signal is also output via standardized 3G-SDI interfaces (the number of these being dependent upon the frame rate) for connection to a system or an external recorder.

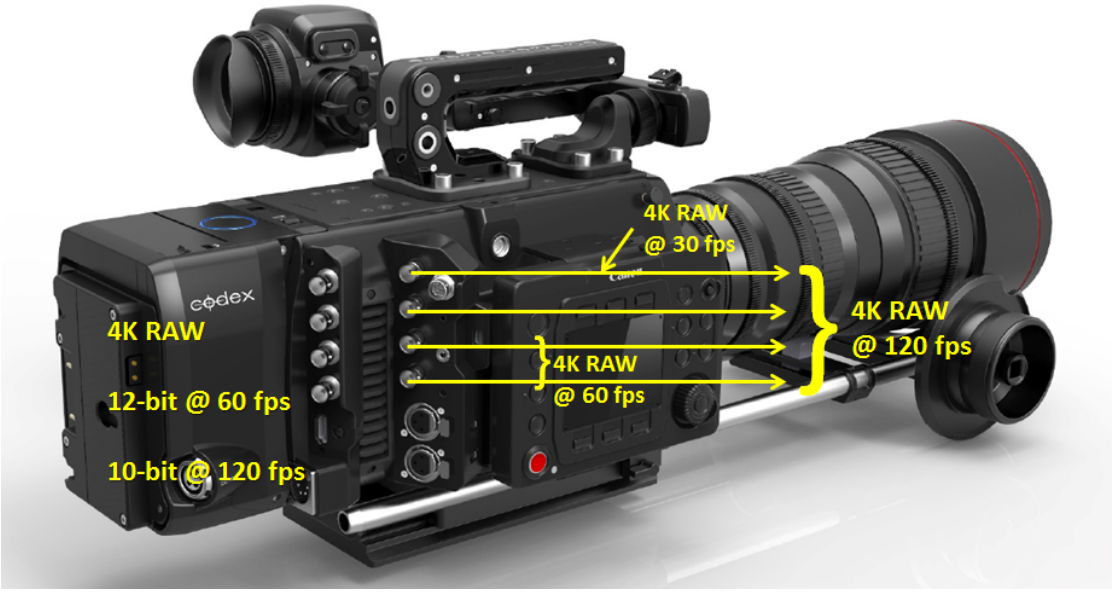

Figure 3 *The EOS C700 with the dockable Codex recorder empowers uncompressed RAW recording while also delivering the 4K RAW signal via 3G-SDI output interfaces (the number of these interfaces is dependent upon the frame rate) to an external system or another recording device*

The combination of the optional Codex CDX-36150 with the EOS C700 camera allows for high-speed 4.5K RAW recording at up to 100fps, 4K RAW at up to 120fps, 4K Apple ProRes at up to 60fps, 2K Apple ProRes at up to 240fps. Recordings are made to the Codex Capture drives.

Table 1 Uncompressed RAW Recording Options in the C700 / Codex CDX-36150

Codex CDX-36150				
Format	Resolution	Color Sampling	Bit Depth	Max Frame Rate fps
4.5K RAW	4512 x 2376	RGB Bayer RAW	12-bit 10-bit	< 60 100
4K RAW	4096 x 2160	RGB Bayer RAW	12-bit 10-bit	< 60 120
Widescreen 2.35:1 (Cinemascope)	4512 x 1920	RGB Bayer RAW	12-bit 10-bit	< 60 120
Crop 2K	2048 x 1080	RGB Bayer RAW	12-bit	240
EXT RAW 3G-SDI Output				
4K RAW	4096 x 2160	RGB Bayer RAW	10-bit	60

4.0 NEW OETF FOR THE 4K / UHD RAW DATA

The video processing of the 4K RAW signal in the EOS C700 is quite different to that in the EOS C500 and EOS C300 Mark II. In those three cameras the same video processing was applied to the on-board recorded video as was applied to their RAW signal outputs. As shown in Figure 1 these same video processes are still applied to the signal that is recorded on board the EOS C700. However, in the case of the 4K RAW signal design steps were taken to further protect the integrity of that signal by eliminating certain video processes (like White Balance, Digital ISO adjustments, and the Linear Matrix that selects the color gamut) and employing a quite different OETF (than the Canon Log, Log 2, or Log 3 that might be selected for the on-board recordings).

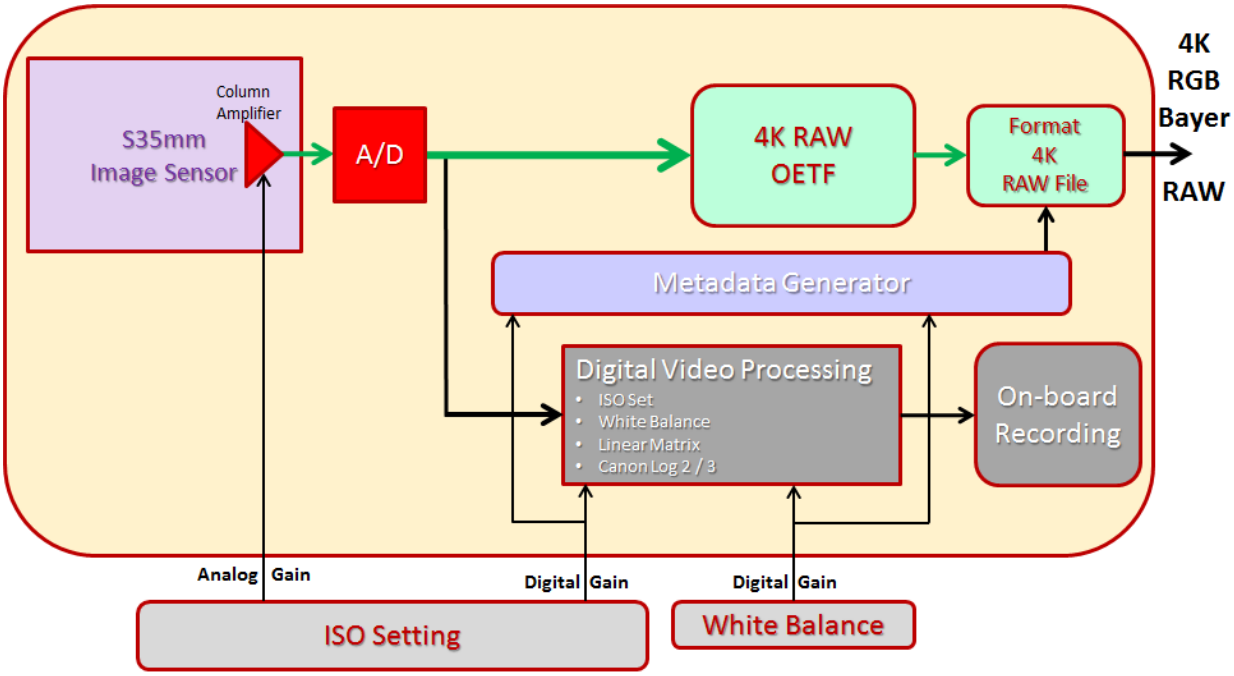

Figure 4 *Parallel tracks within the EOS C700 for 4K RAW recording and for on board recording*

When the main recording format is set to RAW, a special OETF curve optimized for RAW video is used that was designed to implement the following:

1. Use the maximum digital coding regardless of the ISO setting

2. Optimize the lower portion of the OETF curve to the characteristics of the image sensor in those lower regions

3. Shape the mid regions of the curve to better match human vision qualities

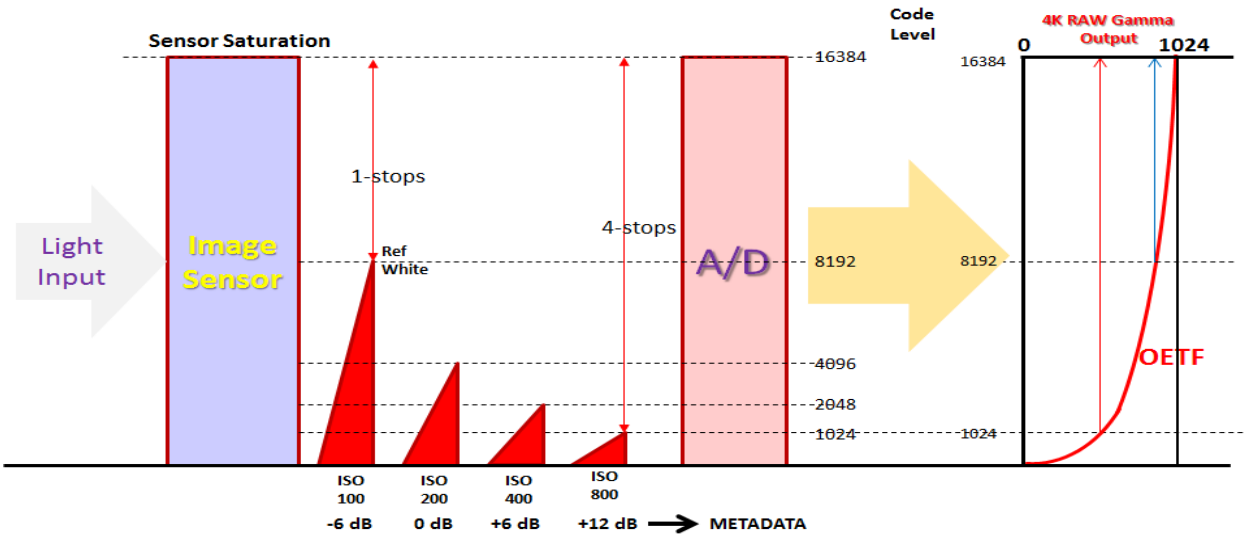

Figure 5 *Illustrating the concept of the special OETF for the 4K Raw data for four exposures*

Figure 5 shows the concept of the 4K RAW Gamma mapping. For the lowest ISO100 setting the analog signal amplitude applied to the A/D converter is large and accordingly the code levels are particularly favorable to the entire signal. However, the dynamic range is curtailed to just one stop above reference white. As the scene illumination lowers the analog output from the image sensor progressively lowers. At ISO 800 the code level for reference white is 1024 which is more than enough to provide an excellent tonal reproduction for the nominally exposed signal – while also having the advantage of having 1600% headroom to support HDR imaging. The RAW Gamma curves or the two levels of ISO 100 and ISO 800 settings are compared with the Canon Log2 curve in Figure 6.

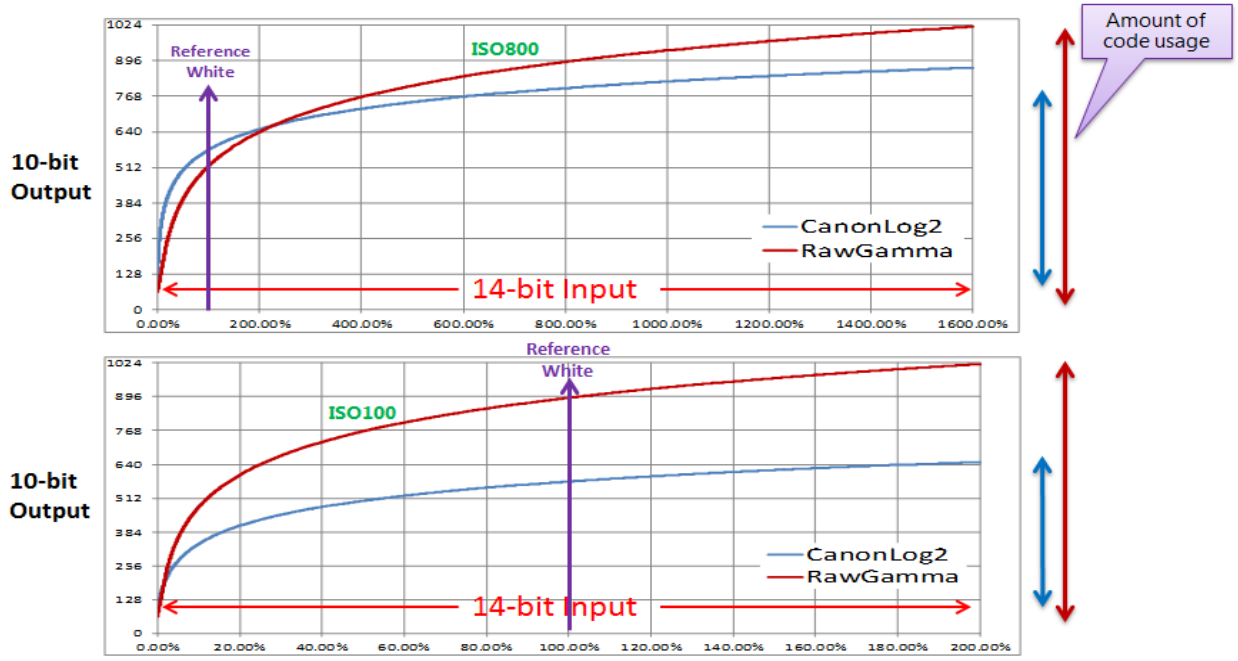

Figure 6 *Showing the new OETF used exclusively on the 4K/ UHD RAW signal in the EOS C700*

5.0 ON-BOARD RECORDING – IN EITHER XF-AVC OR ProRes

As shown in Figure 7 the on-board primary recording uses two CFast memory cards to record any of the chosen 4K / UHD / 2K / HD production formats. At the same time a proxy version for offline editing support is recorded on an SD card at a much lower data rate.

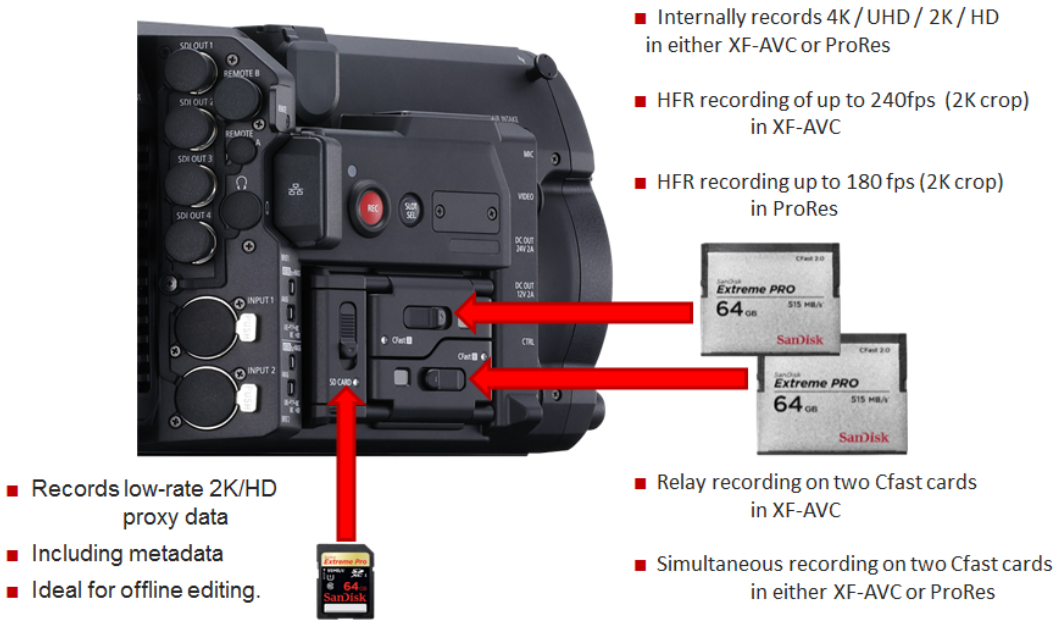

Figure 7 *On-board recording is made to two CFast cards and a proxy representation is recorded on an SD card*

6.0 INTRA ProRes MODE

Three levels of ProRes are available that offer a range of choices in recording data rate:

Apple ProRes 4444: High-quality version of Apple ProRes for 4:4:4:4 image sources (including alpha channels). This codec features full-resolution, mastering quality 4:4:4:4 RGBA color and visual fidelity that is perceptually indistinguishable from the original material.

Apple ProRes 422 HQ: Higher-data-rate version of Apple ProRes 422 that preserves visual quality at the same high level as Apple ProRes 4444, but for 4:2:2 image sources.

Apple ProRes 422: High-quality compressed codec offering nearly all the benefits of Apple ProRes 422 HQ, but at 66 percent of the data rate for even better multistream, real-time editing performance.

NOTE: ***The ProRes recording options are supported by new firmware update which will be released in 2017***

7.0 INTRA XF-AVC MODE – *4K / UHD CAPTURE*

The EOS C700 has extended the XF-AVC recording options beyond those in the EOS C300 Mark II. It can record 4K / UHD YCrCb 4:2:2 up to 50 and 59.94 progressive frames per second at 810 Mbps recording data rate that ensures the highest image capture. The lower frame rates are recorded at 410 Mbps. Variable Bit Rate (VBR) is used and the file wrapper is MXF.

TABLE 2 High-end Intra-frame recording of YCrCb 4:2:2 2160-line 4K and UHD

Codec XF-AVC	Resolution	Color Sampling & Bit Depth	Max Bit Rate (Mbps)	Frame Rates (fps)	Media CFast Recording Duration 128 GB	Media CFast Recording Duration 256 GB
Intra	4K (4096x 2160)	4:2:2 10	810	59.94P / 50P	20 min	40 min
	or					
	UHD(3840x2160)	4:2:2 10	410	29.97P / 25P 24.0P / 23.98P	40 min	80 min

8.0 INTRA ProRes MODE – *4K / UHD CAPTURE*

Apple ProRes codecs take full advantage of multicore processing and feature fast, reduced-resolution decoding modes. Apple ProRes codecs support any frame size including 5K / 4K / UHD / 2K / HDSD at full resolution. The data rates vary based on codec type, image content, frame size, and frame rate. All Apple ProRes codecs deploy intra-frame and variable bit rate (VBR) codec technologies. Table 3 summarizes the on-board ProRes 4K / UHD recordings in the C700. The maximum recordable data rate for 4K / UHD is 29.97 fps.

Table 3 High-end ProRes Intra-frame recording of YCrCb 4:2:2 2160-line 4K and UHD

Codec ProRes	Resolution	Color Sampling & Bit Depth	Max Bit Rates Mbps	Frame Rates fps	Media Cfast Recording Duration 128 GB	Media Cfast Recording Duration 256 GB
ProRes 422 HQ	4K (4096x2160)	4:2:2 10	754 – 940	23.98 / 24 / 25 / 29.97P	21 min	42 min
	or					
	UHD (3840x2160)	4:2:2 10	707 – 834			

9.0 INTRA XF-AVC MODE – *HD / 2K CAPTURE*

This is the recording mode that supports amazingly high image quality capture. In seeking the very highest performance for 2K / HD, the three full bandwidth RGB 4:4:4 components are recorded at 12-bit or 10-bit at the very high data rates shown in Table 4. Variable Bit Rate (VBR) is deployed in this mode because it more flexibly and accurately encodes the video data, with fewer bits assigned to less demanding segments of an image frame and more bits used in difficult-to-encode segments. The file wrapper is MXF.

The alternative YCrCb 4:2:2 component set can also be recorded at 12-bit or 10-bit

TABLE 4 Intra-frame Recording of **RGB 4:4:4** or **YCrCb 4:2:2** for 1080-line 2K and HD

Codec	Resolution	Color Sampling & Bit Depth		Max Bit Rate (Mbps)	Frame Rates (fps)	Media CFast Recording Duration	
XF-AVC						128 GB	256 GB
XF-AVC	2K (2048x1080)	4:2:2	10	310	59.94P / 50	50 min	105 min
	or	4:4:4	12	440	59.94 P / 50P	35 min	75 min
Intra	HD (1920x1080)	4:2:2	12	225	29.97P / 25P / 24.0 / 23.98P	75 min	150 min
		4:4:4	10	410	59.94P / 50P	40 min	80 min
			10	210	29.97 / 25.0 / 24.0P / 23.98 P	80 min	160 min
		4:2:2	10	160	29.97P / 25P / 24.0P / 23.98P	105 min	210 min
	Crop 2K / HD	4:2:2	10		240P Maximum	50 min	105 min
	Base 23.98 / 25P			90	When above 125P		
	Base 59.94P / 50P			170	When above 125P		

10.0 INTRA ProRes MODE – *2K/ HD CAPTURE*

The alternative ProRes codec also offers a choice between recording an RGB 4:4:4 component set or the YCrCb 4:2:2 component set – as shown in Table 5.

NOTE: ***The data rates shown here for Pro Res are tentative. The final values will be updated when the firmware is released in early 2017***

TABLE 5 Intra-frame Recording of **RGB 4:4:4** or **YCrCb 4:2:2** for 1080-line 2K and HD

Codec ProRes	Resolution	Color Sampling & Bit Depth	Max Bit Rates Mbps	Frame Rates fps	Media Cfast Recording Duration 128 GB	256 GB
PR 4444	2K (2048x1080)	4:4:4 12	302 – 377 629 – 754	23.98 / 24 / 25 / 29.97P 50P / 59.94PP	50 min	110 – 85 min 40 min
	HD (1920x1080)	4:4:4 12	264 – 330 551 – 660	23.98 / 24 / 25 / 29.97P 50P / 59.94P	50 min	110 – 85 min
PR 422HQ	2K (2048x2160)	4:2:2 10	201 – 251 419 – 503	23.98 / 24 / 25 / 29.97P 50P / 59.94P	75 min	150 min
	HD (1920x1080)	4:2:2 10	176 – 220 367 – 440	23.98 / 24 / 25 / 29.97P 50P / 59.94P	75 min	150 min
PR 422	2K (2048x2160)	4:2:2 10	131 – 168 280 – 335	23.98 / 24 / 25 / 29.97P 50P / 59.94P	113 min	226 min
	HD (1920x1080)	4:2:2 10	117 – 147 245 – 293	23.98 / 24 / 25 / 29.97P 50P / 59.94P		
	Crop 2K / HD	4:2:2 10	245 – 293	180P maximum	50 min	110 min

The Apple ProRes 422 Codecs are contained within the QuickTime "mov" wrapper.

11.0 XF-AVC LONG GOP – *HD / 2K BROADCAST TELEVISION*

This level uses the considerably more compressed implementation of XF-AVC – utilizing the Long Group of Pictures (termed Long GOP) embodiment of AVC/H.264 to achieve this degree of compression. This dramatically lowers the data rate to 50 Mbps. The format is coded YCrCb 4:2:2 at 10-bit – and, unlike the EOS C300 it can record at frame rates up to 59.94P. It still employs Variable bit Rate (VBR) for the same reason as XF-AVC Intra.

TABLE 6 Efficient Long GOP recording of **YCrCb 4:2:2** 1080-line 2K and HD

Format	Codec	Resolution	Color Sampling Bit Depth	Frame Rates	Max Bit Rate	Wrapper	VBR CBR
2K	**H.264 Long GOP**	2048 x 1080	422 10-bit	23.98 / 24 /25 /29.97 / 50 / 59.94P	50 Mbps	MXF	VBR
HD	**H.264 Long GOP**	1920 x 1080	422 10-bit	23.98 / 24 / 25 / 29.97 / 50 / 59.94P 50 / 59.94i	50 Mbps	MXF	VBR

12.0 XF-AVC PROXY – *LOW DATA RATE FOR OFFLINE EDITING*

To support offline editing of any of the above HD / 2K / UHD / 4K formats, the C700 separately records a low data rate proxy of the format in question. This is an HD or 2K format that is coded as YCrCb 4:2:0 in Long GOP form at 8-bit at frame rates up to 59.94P. While the primary program signal format is being recorded to the CFast memory cards this proxy is recorded in parallel to a separate SD memory card. As shown in Table 7, the recording data rate varies from 24 Mbps to 35 Mbps depending upon the frame rate.

TABLE 7 Highly efficient Proxy Recording of **YCrCb 4:2:0**

Format	Codec	Resolution	Color Sampling Bit Depth	Frame Rates	Max Bit Rate	Wrapper	VBR CBR
2K Proxy	**H.264 Long GOP**	2048 x 1080	420 8-bit	50 / 59.94P	35 Mbps	MXF	VBR
				50 / 59.94i 23.98 / 24.0 / 25.0 / 29.97P	24 Mbps		
HD Proxy	**H.264 Long GOP**	1920 x 1080	420 8-bit	50 / 59.94P	35 Mbps	MXF	VBR
				50 / 59.94i 23.98 / 24.0 / 25.0 / 29.97P	24 Mbps		

13.0 SLOW AND FAST MOTION RECORDING

The EOS C700 can be set to shoot and capture at a wide range of frame rates. Depending upon the choice of recording frame rate and the separate choice of the playback frame rate the EOS C700 can implent either Fast Motion playback (over quite a broad range) or alternatively Slow Motion Playback (over a more modest range) .

Table 8 outlines all of the choices when the camcorder is operating in either the 4K / UHD and the 2K / HD mode. The left hand column identifies the desired playback frame rate and the two adjoining columns identify the digital production format that has been selected. The righthand column then identifies the various frame rates that can be chosen for the actual shooting – depending on whether fast or slow motion effects are sought.

Table 8 Slow and Fast Motion Recording for 4K / UHD / 2K / HD in the EOS C700

Frame Rate	Vertical Resolution	Color Sampling	Shooting Frame Rate
59.94P	2160	YCbCr 4:2:2 10 bit	1 2 3 6 15 30 60
	1080	RGB 4:4:4 10/12 bit	
		YCbCr 4:2:2 10 bit	1 2 3 6 15 30 60 90 120
	1080 (CROP) *1*2		1 2 3 6 15 30 60 90 120 150 180 210 240
29.97P	2160	YCbCr 4:2:2 10 bit	
	1080	RGB 4:4:4 10/12 bit	1 2 3 6 15 30 32 36 40 44 48 52 56 60
		YCbCr 4:2:2 10 bit	1 2 3 6 15 30 32 36 40 44 48 52 56 60 90 120
	1080 (CROP) *1*3		1 2 3 6 15 30 32 36 40 44 48 52 56 60 90 120 150 180 210 240
24.00P 23.98P	2160	YCbCr 4:2:2 10 bit	
	1080	RGB 4:4:4 10/12 bit	1 2 3 6 12 24 26 28 30 32 36 40 44 48 52 56 60
		YCbCr 4:2:2 10 bit	1 2 3 6 12 24 26 28 30 32 36 40 44 48 52 56 60 72 96 120
	1080 (CROP) *1*3		1 2 3 6 12 24 26 28 30 32 36 40 44 48 52 56 60 72 96 120 144 168 192 216 240
50.00P	2160	YCbCr 4:2:2 10 bit	
	1080	RGB 4:4:4 10/12 bit	1 5 15 25 50
		YCbCr 4:2:2 10 bit	1 5 15 25 50 54 58 75 100
	1080 (CROP) *1*2		1 5 15 25 50 54 58 75 100 125 150 175 200
25.00P	2160	YCbCr 4:2:2 10 bit	
	1080	RGB 4:4:4 10/12 bit	1 5 15 25 26 28 30 34 38 42 46 50
		YCbCr 4:2:2 10 bit	1 5 15 25 26 28 30 34 38 42 46 50 54 58 75 100
	1080 (CROP) *1*3		1 5 15 25 26 28 30 34 38 42 46 50 54 58 75 100 125 150 175 200

14.0 AUDIO RECORDING

Like the EOS C300 Mark II the EOS C700 supports four channels of LPCM 24-bit / 48 kHz audio for all on-board recordings. Linear pulse code modulation (LPCM) is a method for digitally encoding uncompressed sampled analog audio information where the quantization levels are linearly uniform. The output signal is automatically changed to 16bit audio when the camera is working in 4K RAW mode.

Figure 8 *Showing the audio inputs to the C700*

15.0 SUMMARY

The EOS C700 is a first unit camera (A-camera) that offers a choice in origination of any of the four 4K / UHD / 2K / HD standardized production formats. High quality on-board recording of all of these formats is included. Two separate on-board recording codecs – the Canon XF-AVC or the Apple ProRes – offer flexibilities in meeting diverse workflows for episodic television production or theatrical motion picture production. High frame rate recording – up to 60P for the 4K / UHD formats and up to 120 fps for 2K / HD formats is supported. For the 2K/ HD crop format the recorded frame rate can be as high as 240 fps.

Separately, 4K / UHD RAW recording at 12-bits up to 60 fps, or 10-bits up to 120 progressive fps, in a compact dockable recorder thrusts the C700 to an outstandingly high level of image capture. In addition, a future firmware update to the camcorder will support recording 4.5K RAW at 10-bit up to 100 fps. Apple ProRes can also be recorded in this dockable recorder. HDR and WCG image enhancements are applicable to all of the production formats.

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