

WHITE PAPER

EOS C700 FF

Full Frame

Digital Cinema Camera

Version #11

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CINEMA EOS

Canon

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Abstract

It has been a seven-year march for Canon in their progressive roll out of a broadening family of Cinema EOS lenses, cameras, and reference displays. NAB 2018 saw the formal introduction of the Full Frame EOS C700 FF digital cinema camcorder.

Canon's extensive experience with full frame imaging in the still photography domain – based upon the 1.5:1 aspect ratio format (having an active image size of 36mm x 24mm and an image circle having a 43.2mm diameter) – spurred development over many years of a wide-ranging family of supporting prime and zoom lenses. While these are largely used for still image photography they have more recently also been extensively adopted for digital motion imaging. It was with this in mind that the EOS C700 FF deploys a Canon-developed full frame CMOS image sensor that retains that same image circle size. But, an important adjustment was made to the aspect ratio – it is the standardized DCI aspect ratio of 1.896 : 1 (also identified as 17:9) – in recognition that the intent for EOS C700 FF is for digital motion imaging.

Among the five competitive Full Frame systems that have recently emerged no two are alike – they vary in the designs of their respective full frame image sensors and in their associated video processing and recording systems. This white paper is intended to highlight all that is unique in the EOS C700 FF.

The EOS C700 FF retains the basic photosite design of the C300 Mark II and the C700 – a dual photodiode system with an aggregate photosite size of 6.4 micrometers squared – ensuring the same 15-stop dynamic range in all three cameras. However, the photosite count is considerably higher at 5952 (H) x 3140 (V) in the EOS C700 FF. This is 2.11 times the photosite count in native 4K (4096 x 2160).

This dual photosite technology also empowers the acclaimed Dual Pixel CMOS Auto Focus system (or Focus Guide alternative) which has special importance for 5.9K high resolution imaging.

*A distinguishing design strategy in the EOS C700 FF is a significant enhancement of the digital representation that is recorded on-board on two CFast 2.0 cards – using either the Canon XF-AVC or the Apple ProRes codec. The process starts with the native 5.9K Bayer encoded data being deconstructed – without any algorithmic decoding – into four components of red, blue, and two green. This avoids any reconstruction errors. They are then interpolated up to three individual red, green, and blue 5952 x 3140 components. These are then downsampled to three 4K RGB components that are carefully filtered. This **“Oversampling 4K Processing”** produces a 4K digital production format that has:*

- 1. Significantly higher MTF than native 4K origination*
- 2. A displaced aliasing sideband resulting in attenuated presence of aliasing in the baseband 4K*
- 3. Filtering that protects the baseband MTF up to the Nyquist frequency of 2160 TVL/ph*
- 4. Associated noise averaging that lowers the visibility of this noise*

The paper will explain this process in more detail.

The use of anamorphic lenses has become popular again with the advent of full frame digital cinema cameras – the additional image sensor height is particularly favorable to this. The paper will discuss in detail the various widescreen and anamorphic options supported by the EOS C700 FF.

1.0 EOS C700 FF JOINS THE RANKS OF FULL FRAME CAMERAS

For some time, in the digital DSLR camera domain, the Full Frame image format signifies a 1.5:1 aspect ratio determined by the 36mm x 24mm active image dimensions – shown in Figure 1. This size is a legacy of the earlier days of 35mm film cameras whose image size was also 36mm x 24mm.

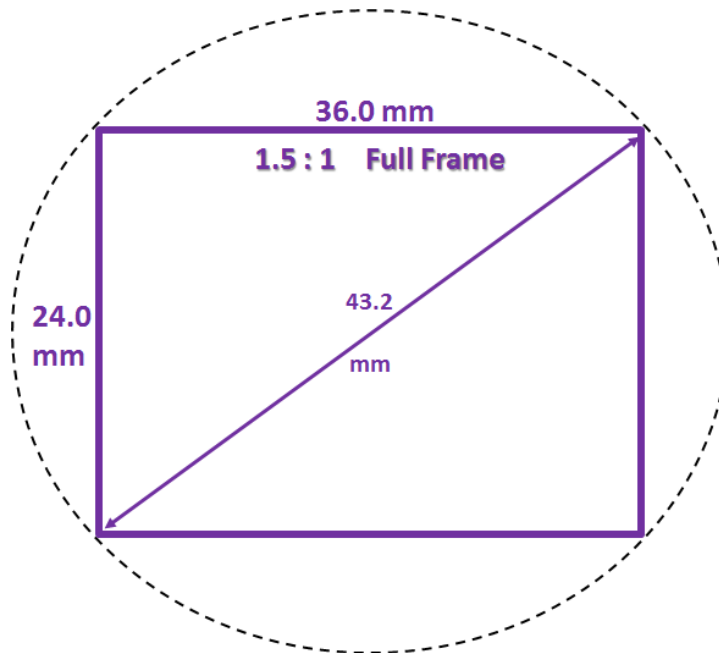


Figure 1 The traditional Full Frame image format has an aspect ratio of 1.5 : 1 and an image circle having a diameter of 43.2mm

This image format is central to the newly emerging series of full frame digital cinema cameras that have entered the marketplace during the past two years. Yet, just as is the case with the now extensive range of competitive Super 35mm digital cinema cameras, there are many deviations from this familiar image format among the emerging manufacturers.

The Canon Full Frame C700 FF digital cinema camera made its formal debut at NAB 2018. This now makes a list of five such competitive large format cameras:



2.0 EOS C700 FF – THE FULL FRAME CMOS IMAGE SENSOR

Figure 2 shows the new large format image sensor used in the new EOS C700 FF camera – with the red outline defining the active image area.

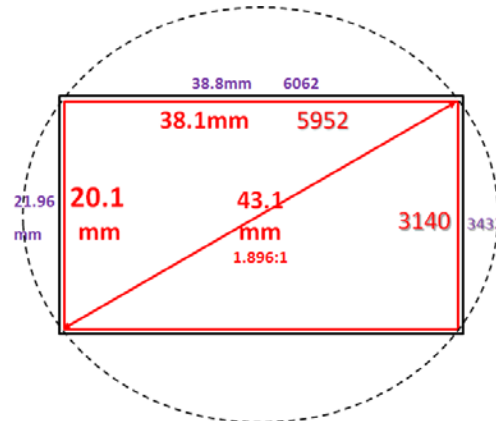


Figure 2 *The EOS C700 FF image sensor has the digital cinema DCI aspect ratio of 1.896:1 (sometimes termed 17:9) – unlike the 1.5:1 aspect ratio of the Full Frame DSLR image format*

The pivotal image sensor design decisions were:

- Maintain the same dual pixel photosite with the same individual aggregate size of 6.4 micrometers squared as the EOS C300 Mk II and EOS C700
- Large format CMOS image sensor having the DCI aspect ratio of 1.896:1 (or 17:9) but having 2.11 times more photosites than the EOS C700 Super 35mm image sensor
- Maintain an Image circle diameter essentially equal to that of the 1.5:1 Full Frame DSLR

Of Special Note: (a) Active image is wider than that of the traditional 1.5:1 full frame ; (b) ALL of the active photosites contribute to the 17:9 frame (compared to reduced number if 1.5:1 frame used).

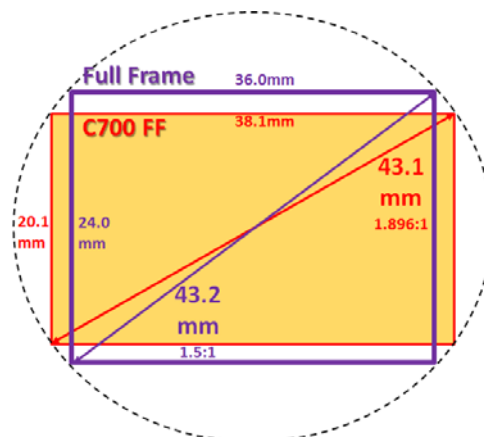


Figure 3 *The EOS C700 FF image sensor does maintain an image circle diameter (43.1mm) almost identical to that of the 1.5:1 Full Frame image format (43.2mm)*

3.0 COMPARISON OF LARGE FORMAT SIZES AND ASPECT RATIOS

Figure 4 directly compares the sensor image formats of the five competitive full frame cameras – here drawn to scale. It is interesting to note that the Arri Alexa LF and the Sony Venice are quite close in size and aspect ratio. RED Monstro 8K / Panavision DXL2 and EOS C700 FF are both wider and are also remarkably close in size and shape.

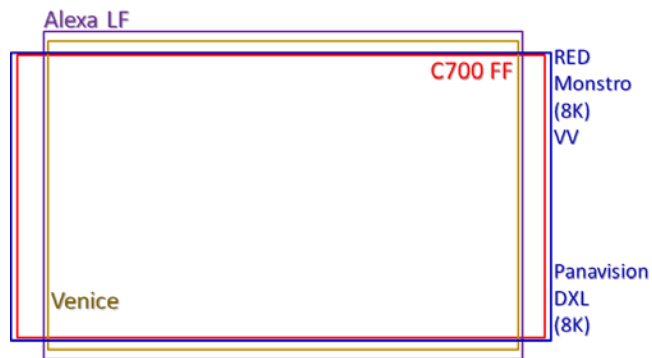


Figure 4 Direct comparisons between the four competing Large Format image sensors

4.0 EOS C700 FF WITH FF LENS – IMAGE SENSOR READOUT MODES

When used with a full frame cine lens the EOS C700 FF has a menu selection that switches Image Sensor Readout modes between the following:

1. Full Frame with 17:9 aspect ratio
2. Native 4K (either DCI or UHD)
3. Native 2K (either DCI or HD)
4. Various Anamorphic modes – including 2 x and 1.3 x and 1.5x

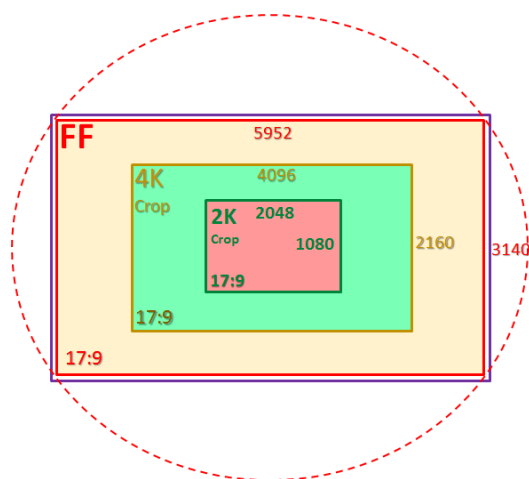


Figure 5 The basic native image sensor readout modes that are menu selected in the EOS C700 FF

5.0 EOS C700 FF WORKS WITH A RANGE OF CINEMA LENS FORMATS

The EOS C700 FF can be used with a range of cinematography lenses – that include full frame lenses, Super 35mm lenses, Super 16mm lenses, and even 2/3-inch broadcast zoom lenses (using Canon B4 mount to PL/EF optical adaptors) – as shown in Figure 6.

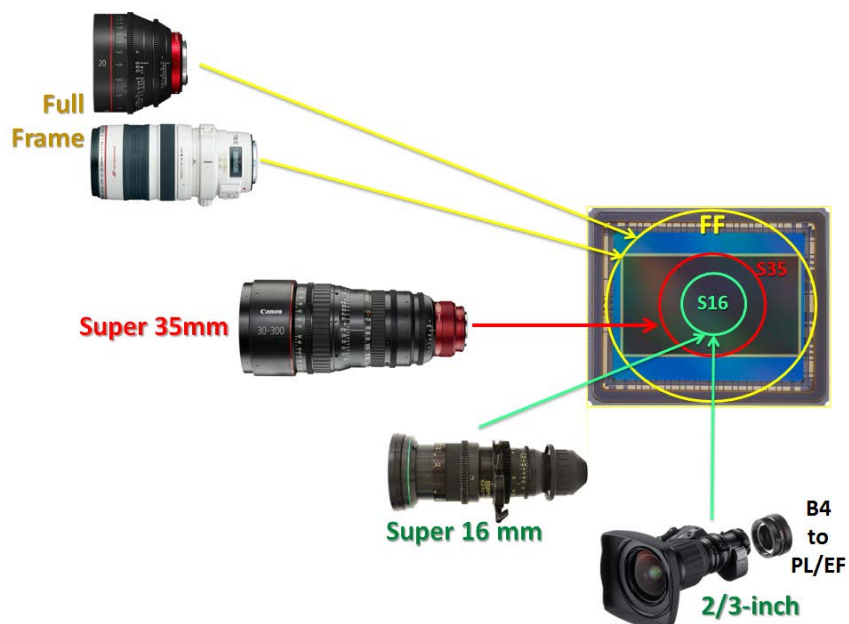


Figure 6 *The C700 FF can be used with all forms of cine and broadcast lenses*

Depending upon the selected lens image format size the Image Sensor Readout menu selection delivers the appropriate cropped digital production format – selected as either 4K DCI or 4K UHD or 2K DCI or full HD – as outlined in Figure 7. The Super 35mm lens can deliver a choice of 4K / UHD / 2K / HD.

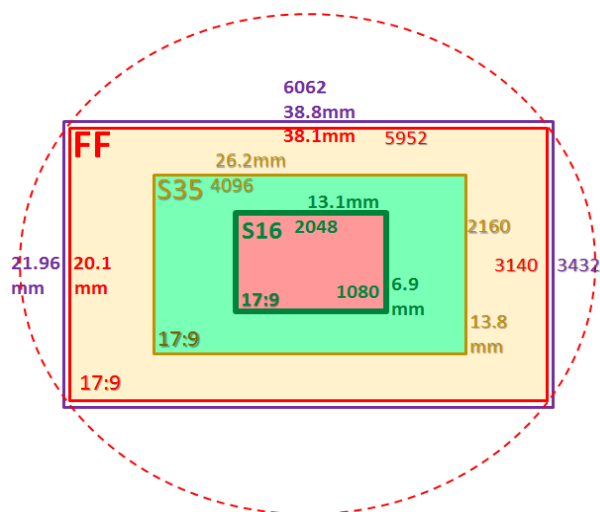


Figure 7 *Showing the three native image formats that are selectable depending upon the image circle size of the chosen cinema lens – the Sensor Readout mode can select between 4K DCI or UHD and 2K DCI or HD*

6.0 DEPTH OF FIELD POSSIBILITIES WITH C700 FF

A great deal of industry discussion on full frame imaging attributes centers about the depth of field possibilities of this larger image format. It is important to bear in mind that depth of field is primarily determined by the optical system (with a secondary modification based on the size of sensor photosite) – very specifically, the focal length setting of the lens. Distance from lens to subject, and lens aperture settings also have a significant bearing on the depth of field.

By way of illustration we will compare two lens camera systems – one, the EOS C700 having a Super 35mm lens, and side by side with it an EOS C700 FF having a full frame lens. The two lens apertures are set to be identical. If the two cameras are then framed for identical field of views (producing identical video images) – then the EOS C700 lens will have a distinctly shorter focal length setting – simplistically simulated in Figure 8.

As a consequence, the EOS C700 FF will exhibit a noticeably more shallow depth of field. Moving one camera relative to the other, and /or altering relative lens aperture settings, can significantly lower the difference in depth of field between the two systems (as well as impacting other aspects of the imagery).

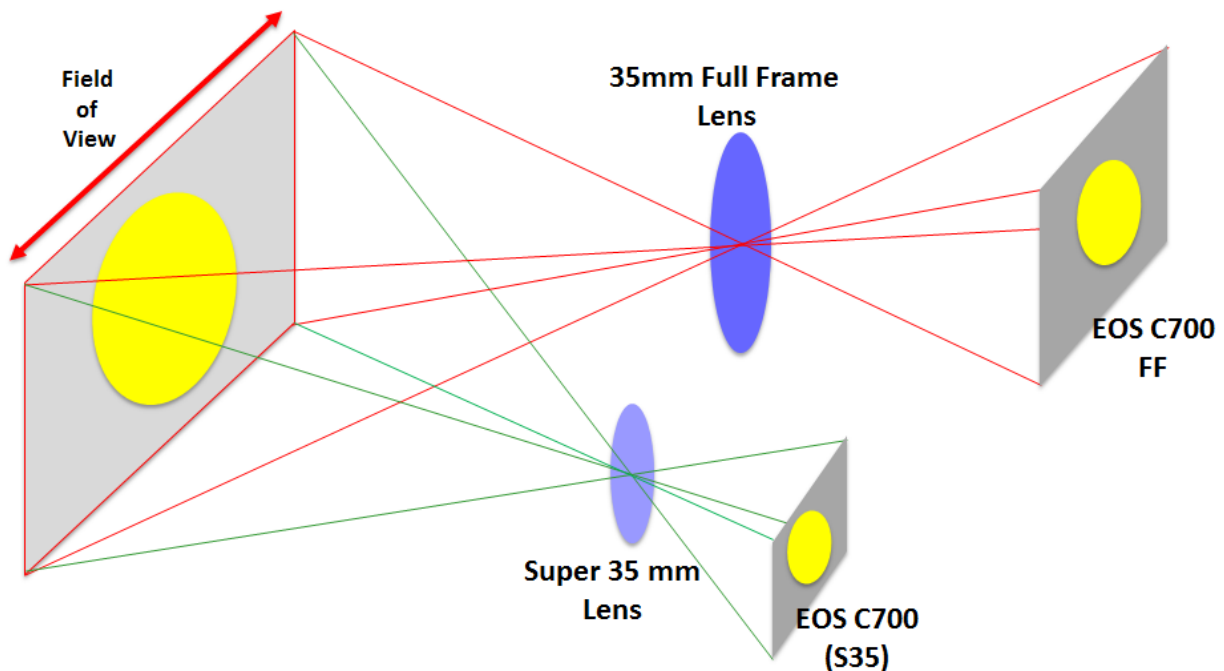


Figure 8 If a EOS C700FF and an EOS C700 are side by side, lens aperture settings are identical, and *both are framed to produce identical images*, the EOS C700 Super 35mm lens will have a shorter focal length setting than the EOS C700 FF lens

To illustrate this difference in focal lengths a simple test was conducted with an EOS C700 (with Super 35mm lens) side by side with an EOS C700 FF (with a full frame lens). The subject was positioned nine feet from the two lens fronts. Both lenses were set to T-4 and the EOS C700 lens was adjusted to frame the image on the right in Figure 9. Note that the speculars in the background are close to being in focus. The EOS C700 FF lens focal length was then adjusted to match the framing of the Super 35mm system – shown on the left in Figure 9. The visible defocusing of the specular background indicates the shorter depth of field of the full frame system.

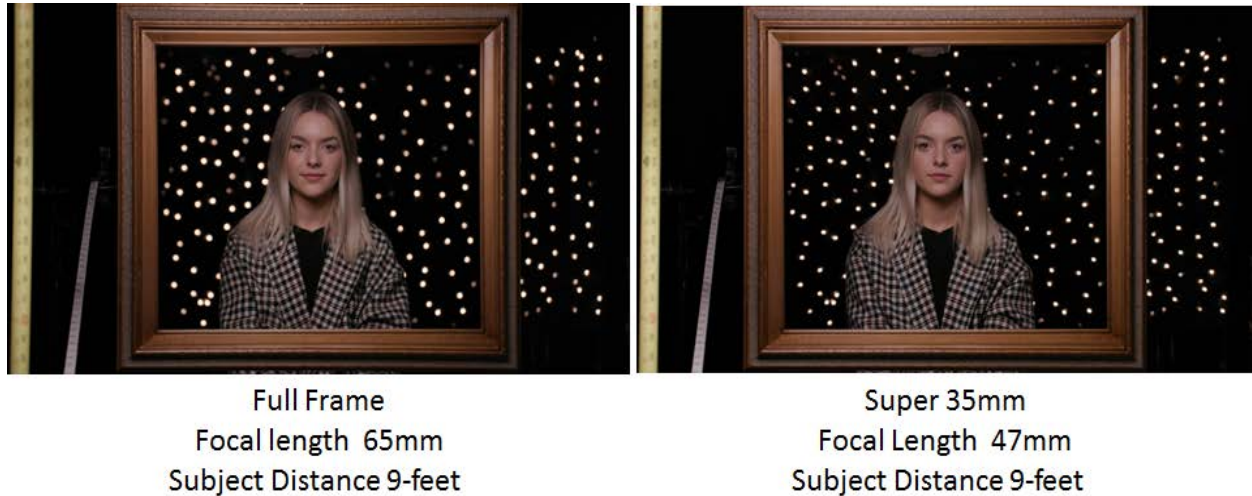


Figure 9 Side by side test with S35mm EOS C700 system and full frame EOS C700 FF system – both lenses at T-4 and focal lengths set to match image framing

If the lens is set at maximum relative aperture, then the depth of field of the EOS C700 FF lens-camera system will be particularly shallow.



Figure 10 Examples of aesthetic imagery that is possible when using very short depth of field

7.0 DUAL PIXEL CMOS AUTO FOCUS SYSTEM

The EOS C700 FF embodies a powerful auto focus system where the sensing of sharp focus takes place within the image sensor photosite itself. Dual photodiodes within each photosite create two separate images A and B that facilitate a phase detection system indicating the degree of defocusing. Both A and B data streams are fed to a processing system that makes all of the decision-making and data manipulation associated with the Auto Focus system. This is especially powerful with a 5.9K resolution image sensor.

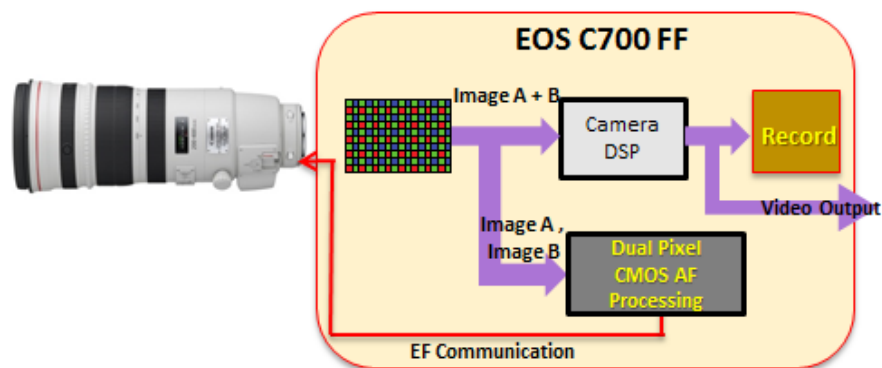


Figure 11 Showing the separate processing of the dual pixel data from the image sensor for Auto Focus

7.1 Focus Guide System

For the cinematographer who prefers traditional creative manual focus operation the dual pixel system can alternatively be switched from the Auto Focus control loop encompassing the lens focus control to an open loop system that utilizes the Dual Pixel CMOS AF data processing to instead transfer precision signaling in the camera viewfinder that indicates both required rotation direction to achieve sharp focus and confirmation when that focus is achieved .

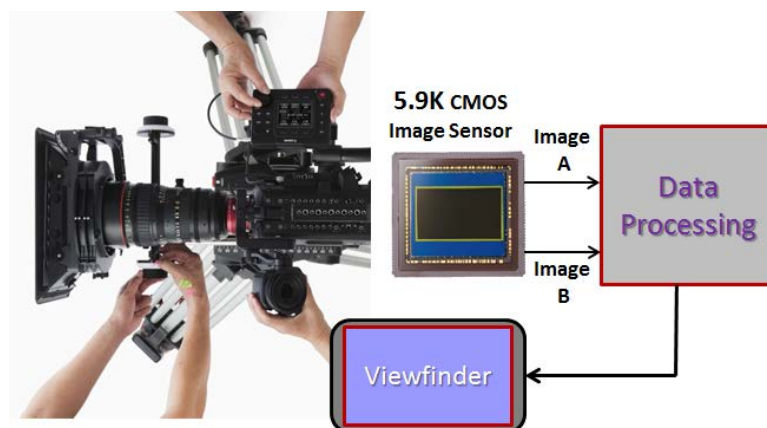


Figure 12 Principle of the Focus Guide system – where manual actuation of the lens focus control is detected within the image sensor and the data processing signals focusing directions in the viewfinder

8.0 EOS C700 FF RECORDING FORMATS

1. **RAW Recording** – uncompressed 5.9K in a dockable Codex recorder CDX-36150
2. **On-board Recording** – choice of either an XF-AVC codec or ProRes codec
3. **On board Recording** – choice of 4K DCI or 4K UHD digital production formats
4. **On-board Recording** – choice of 2K DCI or 1080-line HD digital production formats

8.1 RAW Recording

The Codex CDX-36150 directly docks to the EOS C700 FF and the RAW recording options are shown in Table 1

Table 1 RAW Recording Options in EOS C700 FF

Codex CDX-36150				
Maximum Frame Rates with a Base of 23.98 fps				
Format	Resolution	Color Sampling	Bit Depth	Max Frame Rate fps
5.9K RAW	5952 x 3140	RGB Bayer RAW	10-bit	60P
			12-bit	23.98P/24/25/29.9P
Widescreen 2.35:1 (Cinemascope)	5952 x 2532	RGB Bayer RAW	10-bit	60P
			12-bit	23.98P/24/25/29.9P
4K RAW (Super 35mm Crop)	4096 x 2160	RGB Bayer RAW	12-bit	60P
			10-bit	72P
2K Crop RAW (Super 16mm Crop)	2048 x 1080	RGB Bayer RAW	12-bit	60P
			10-bit	168P
EXT RAW				
3G-SDI Output				
4K RAW	4096 x 2160	RGB Bayer RAW	10-bit	60P

The integrity of the RAW signal is protected by eliminating video processes like White Balance, Digital ISO adjustments, and the Linear Matrix that selects the color gamut, and employing a special OETF termed RAW Gamma that optimizes the digital coding over the entire transfer curve [1].

8.2 On-board Recording:

Choice of two recording codecs – Canon **XF-AVC** codec or the Apple **ProRes** codec – to record:

1. 4K DCI or UHD production formats downsampled from Full Frame – up to 60 fps (XF-AVC)
2. 2K DCI or full HD production formats downsampled from Full Frame – up to 60 fps
3. 4K DCI or UHD production formats cropped from Full Frame – up to 60 fps (XF-AVC)
4. 2K DCI or full HD cropped from Full Frame – up to 168 fps (23.98 base) and 150 fps (29.97 base)

8.3 Preparation of the 4K Video for On-board Recording:

To accomplish on-board image capture, the Canon EOS C700 FF implements a unique **“Over Sampling 4K Processing”** – a processing algorithm that effectively mobilizes the significant resolution of the 5.9K sensor to produce outstanding image quality for 4K DCI / UHD and 2K / HD recording. This recording can use either of the XF-AVC or ProRes on-board codecs. To understand the innovation of this processing it is helpful to first examine the innate challenge of native 4K origination.

8.4 Traditional Native Origination of 4K

Native origination of the 4K digital production format within a 4K image sensor (having 4096 horizontal samples) entails a horizontal sampling frequency of 4320 TVL/ph. Sidebands are created due to that sampling process and Figure 13 shows how the first order sideband – which is centered about that sampling frequency – is the most challenging in terms of the creation of aliasing. When that sideband overlaps with the baseband spectrum aliasing components are generated that contaminate the baseband signal. Optical pre-filtering is typically employed to strike a balance between an acceptable baseband MTF and a modest degree of aliasing – as typified in Figure 13.

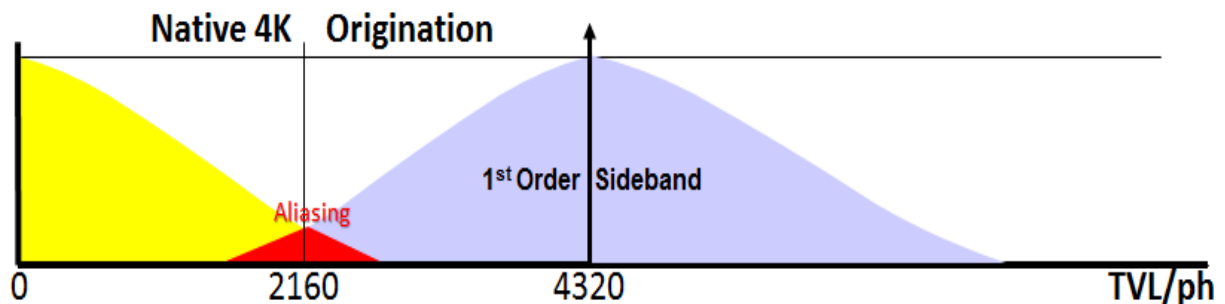


Figure 13 Showing a hypothetical 4K camera baseband signal (in yellow) having a Nyquist frequency of 2160 TVL/ph and the sampling sideband that causes aliasing

8.5 EOS C700 FF – Debayer and Oversampling 4K Processing

What is very important in the EOS C700 FF is that the construction of the red, green, and blue components entails no algorithmic debayering processes. A unique parallel readout process within the 5.9K image sensor directly extracts the four individual components – including the two spatially offset green components (green having twice as many spatial samples as the red and blue components). This innovative approach totally avoids any of the reconstruction errors inevitably associated with algorithmic debayering and this helps contribute to a clean artifact-free final recorded image.

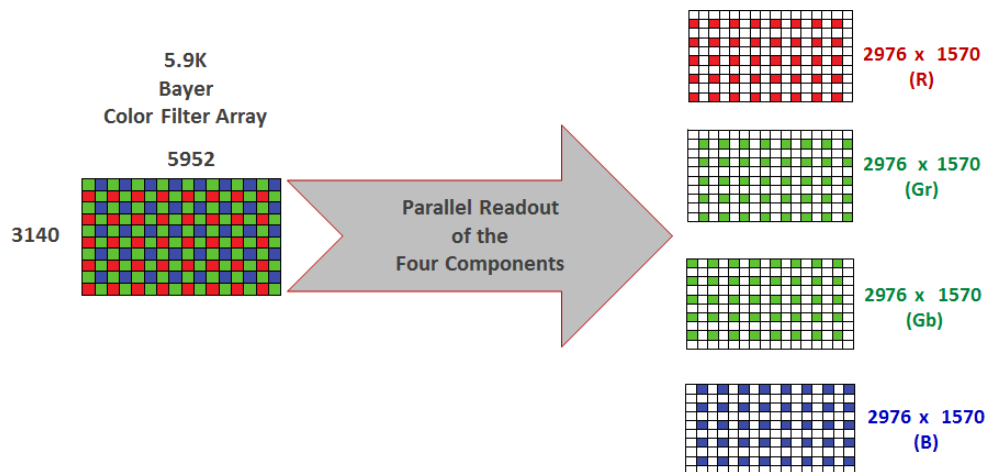


Figure 14 The C700 FF image sensor directly reads out four parallel components from the 5.9K Bayer image sensor

To overcome the limitations of native 4K sampling an important first step in the EOS C700 FF is an oversampling process based upon the higher 5.9K image sensor sampling. The extracted two green components are summed and then all three of the RGB components are separately interpolated to form three 5.9 K frames as shown in Figure 15.

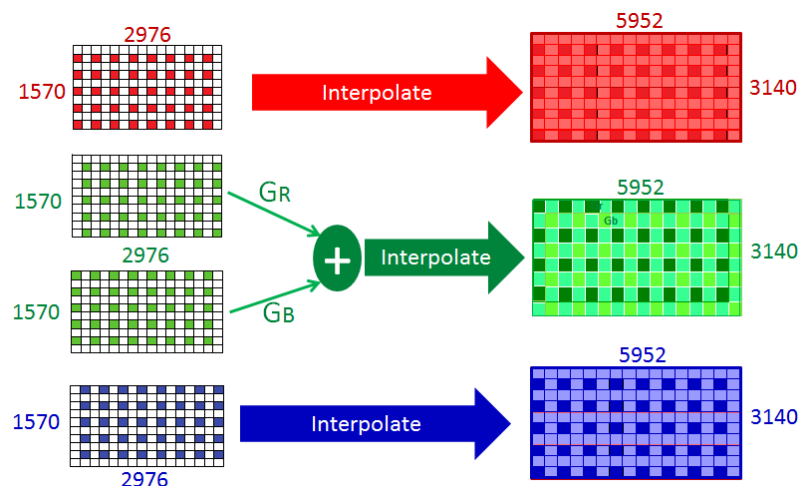


Figure 15 Three RGB frames each having a digital sampling structure of 5952 (H) x 3140 (V) are created.

This elevated number of samples corresponds to a spatial sampling frequency of 6280 TVL/ph – as shown in Figure 16 (b) which is considerably higher than the 4320 TVL/ph sampling frequency of a native 4K system shown in Figure 16 (a).

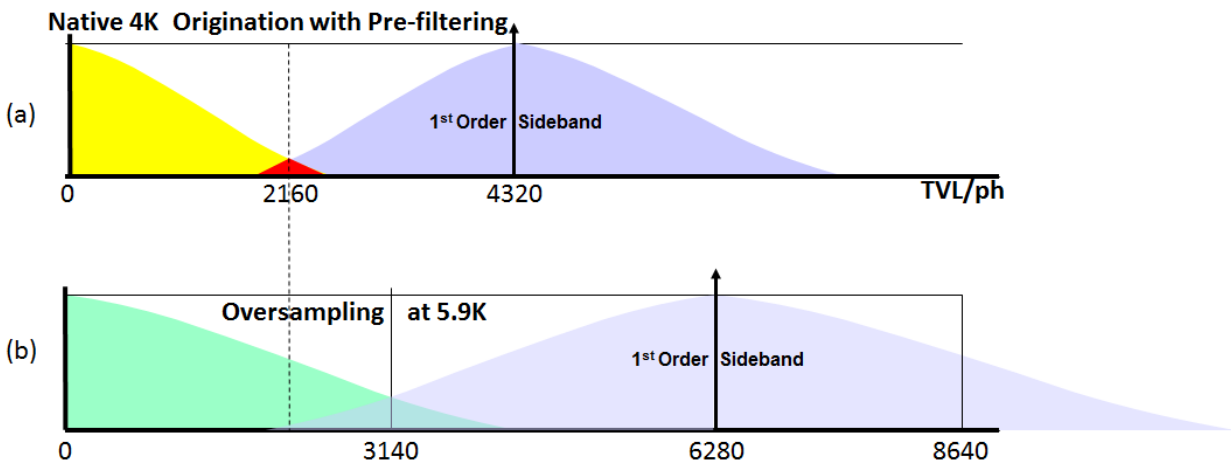


Figure 16 Showing the relative baseband and first order sidebands of a native 4K (a) and the EOS C700 FF 5.9K (b) RGB digital sampling systems

The second critically important step in the overall process is the downsampling of these three 5.9K components to the standardized 4K (selectable as DCI or UHD) components.

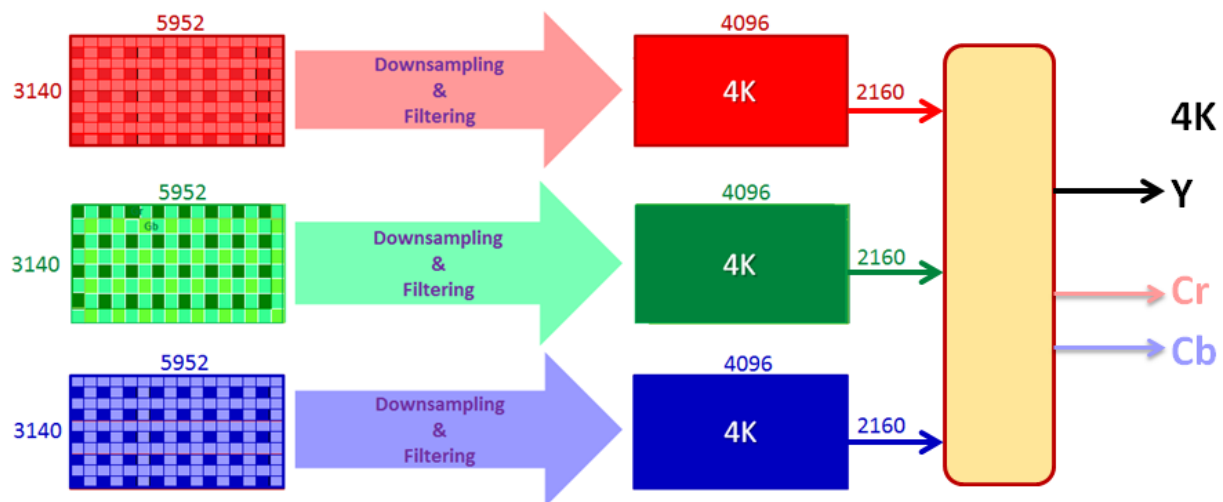


Figure 17 The 5.9K RGB components are digitally downsampled and filtered to produce 4K RGB components

The downsampling process produces a set of 4K RGB baseband components that have been spatially separated from their respective 1st order sideband signals (which remain centered at 6280 TVL/ph) as shown in Figure 18 (c).

This all-important opening of spectral space between the two virtually eliminates a major aliasing contributor and sustains a high MTF right up to the traditional Nyquist limit for 4K (2160 TVL/ph). It further allows implementation of sophisticated filtering that protects that elevated baseband 4K MTF profile while eliminating any ringing. These RGB components are matrixed to a 4K set of YCrCb 4:2:2 component set with the Luma signal having enhanced MTF – shown as the additional green area superimposed on the native 4K Luma MTF as illustrated in Figure 18 (c) – that results in images that are visibly sharper than natively originated 4K that has been optically pre-filtered to avoid aliasing as shown in (a) of Figure 18.

And, most important, that enhanced 4K YCrCb 4:2:2 set is captured on board – in a choice of two high performance recording codecs.

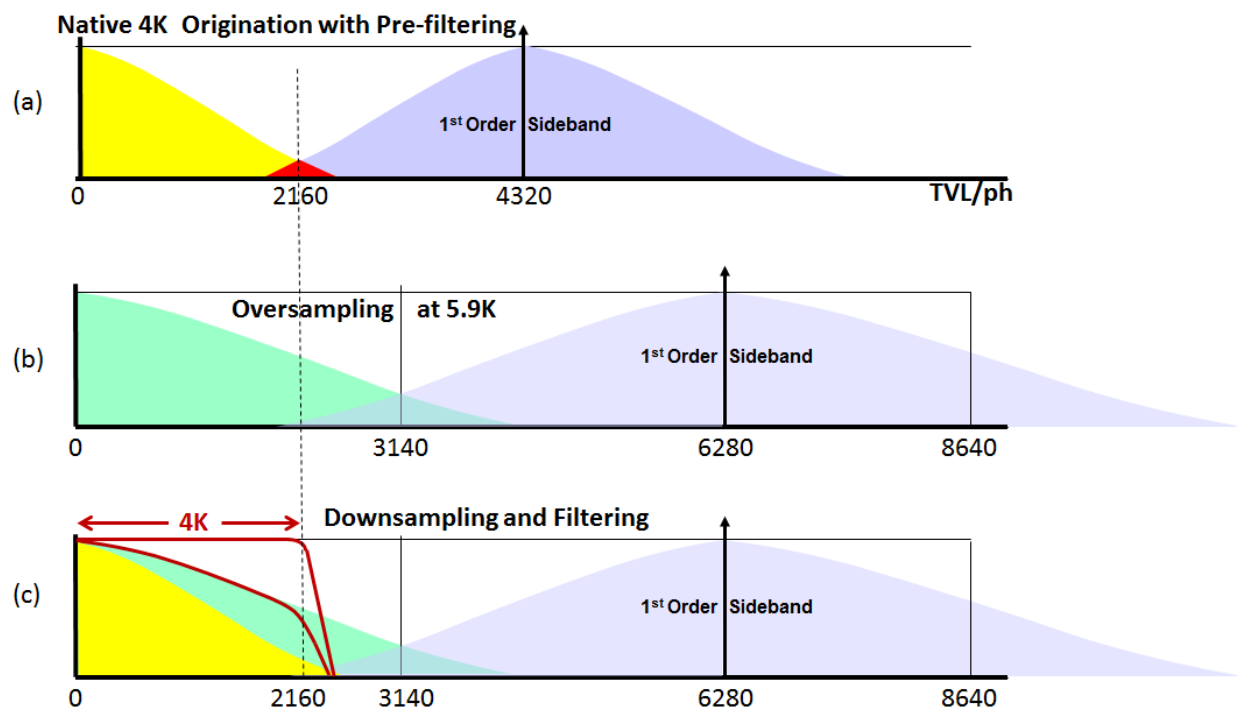


Figure 18 The downsampling process retains the higher baseband MTF of the 5.9 K signals and allows filtering to implement a well-controlled roll-off around the 4K Luma band edge as shown in (c)

Equally important, this processing entails noise-averaging that improves the subjective appearance of the noise which in turn supports sharp and clean images especially at the higher ISO settings.

There are two ways that this enhanced 4K can be creatively capitalized upon:

1. For a specific image framing – the EOS C700 FF records a 4K that is visibly sharper and cleaner than a natively originated 4K
2. A wider image capture (more image content) by the EOS C700 FF can be adapted to the 4K container and not lose significant sharpness

8.6 Unique Image Capture Benefit of Oversampling 4K Processing

Having a full frame camera that can record on-board all of the many forms of imagery offered by this large image format – and do so with an enhanced performance – is a significant advantage of the EOS C700 FF. This can be illustrated with a variety of examples. One such example is offered by consideration of the scene shown in Figure 19.



Figure 19 Wide panoramic scene intended to be imaged by the C700 FF using two different lenses

If a Super 35mm lens is mounted on the EOS C700 FF and its focal length is set to frame a respectably wide image that 4K resolution will reproduce with requisite sharpness – then it might be as shown within the inner green rectangle in Figure 20. If the S35 lens is now replaced with a full frame lens that is set to the same focal length, then the captured image will be that shown bounded by the red rectangle. Note that it captures an image that is wider than the traditional 1.5:1 full frame image sensor – and it has 2.1 times more image content than that of the first S35 capture (but has the same resolution per unit area as the S35 image).

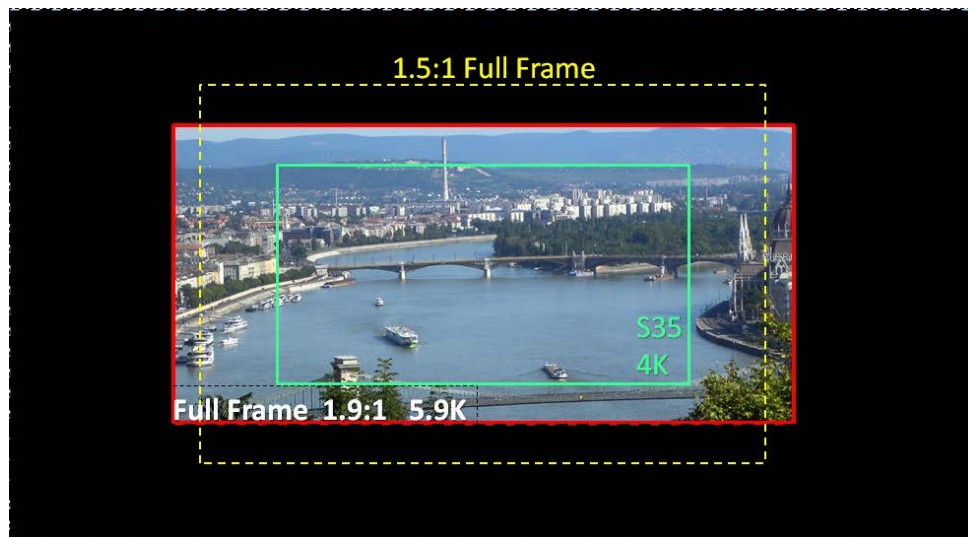


Figure 20 Comparing EOS C700 FF image capture of a Super 35mm lens with that of a full frame lens set to the same focal length shows the considerably greater image content captured by the latter

When the full frame 5.9K image is passed through the *Oversampling 4K Processing* within the EOS C700 FF it will be faithfully reproduced within the standardized 4K (4096 x 2160) container as shown in the lower half of Figure 21 below. Directly comparing this to the 4K cropped image that was captured by the EOS C700 FF using the Super 35mm lens – shown in the upper portion of Figure 121– clearly shows the dramatic difference in scene content. And, most important – the elevated sharpness of the downsampled 4K will sustain all of that additional scene detail.

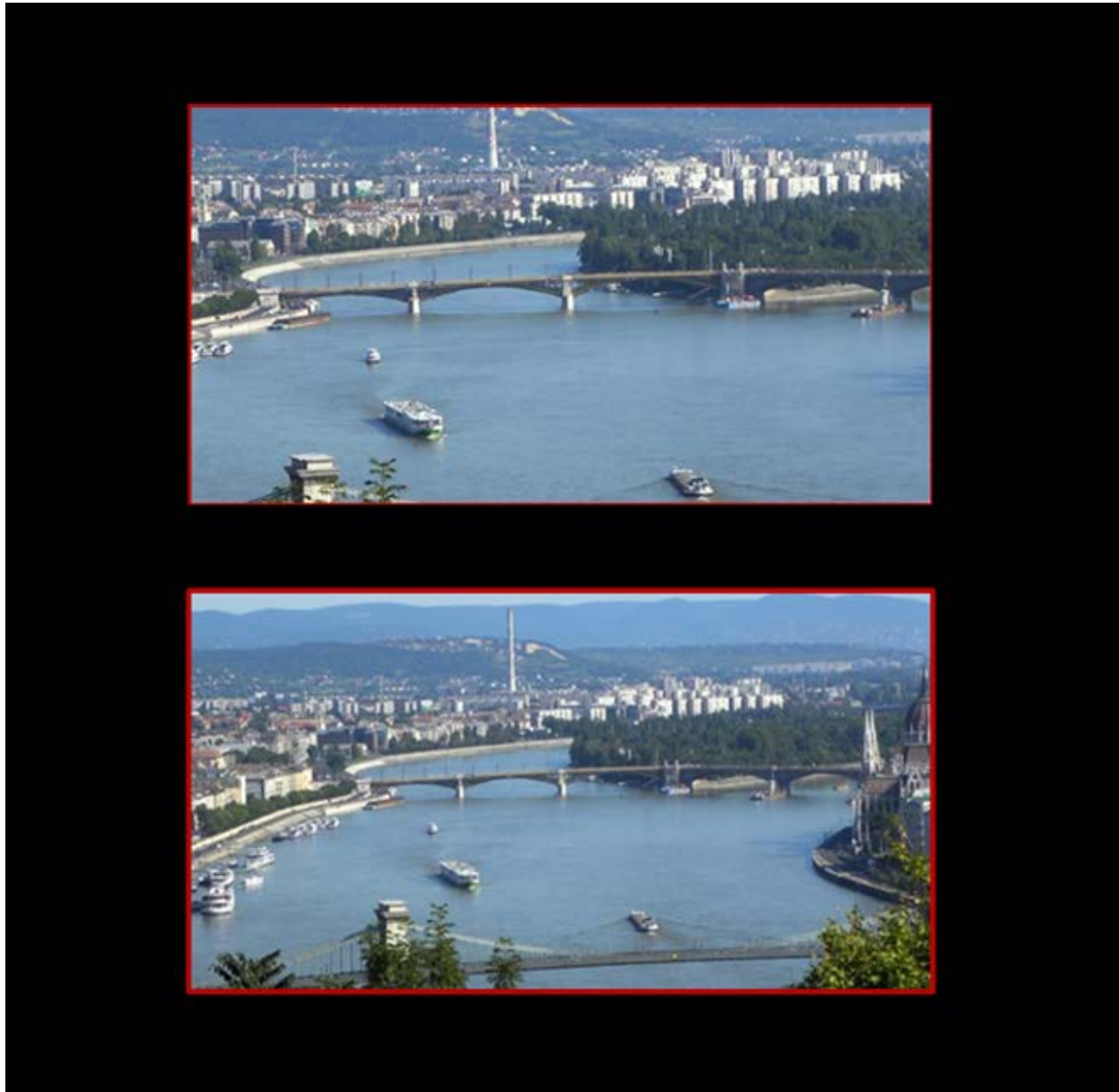


Figure 21 Comparing the wide full frame 4K downsampled image (lower) with the 4K image using the Super 35mm lens (upper)

9.0 ON-BOARD RECORDING IN XF-AVC

9.1 Full Frame Sensor Capture Mode

When the full frame lens and camera capture in 5.9K the downsampled 4K / UHD or the 2K / HD can be recorded using the XF-AVC codec according to the options shown in Table 1

TABLE 1 Intra-frame recording of YCbCr 4:2:2 2160-line 4K and UHD or 1080-line 2K/HD

Codec	Resolution	Color Sampling & Bit Depth	Max Bit Rate (Mbps)	Frame Rates (fps)	Media	CFast
					Recording Duration	
					128 GB	256 GB
XF-AVC	4K (4096x 2160)	4:2:2 10	810	59.94P / 50P	20 min	40 min
	or	4:2:2 10	410	29.97P / 25P	40 min	80 min
	UHD (3840x2160)			24.0P / 23.98P		
XF-AVC Intra Sensor Full Frame		4:4:4 12	440	59.94 P / 50P	35 min	75 min
		4:4:4 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
		4:4:4 10	210	29.97 / 25.0 / 24.0P / 23.98P	80 min	160 min
		4:2:2 10	310	59.94P / 50P	50 min	105 min
XF-AVC Long GOP		4:2:2 10	50	29.97P / 25P / 24.0P / 23.98P	335 min	680 min

9.2 Super 35mm Crop Mode

When a Super 35mm lens is used on the EOS C700 FF the 4K / UHD or the 2K / HD formats can be selected for recording in the XF-AVC codec according to the options shown in Table 2

TABLE 2 Intra-frame Recording for the Super 35mm Crop Mode

Codec	Resolution	Color Sampling & Bit Depth	Max Bit Rate (Mbps)	Frame Rates (fps)	Media CFast		
					Recording Duration		
					128 GB	256 GB	
XF-AVC Intra Super 35mm Crop	4K (4096x 2160) or UHD (3840x2160)	4:2:2 10	810	59.94P / 50P	20 min	40 min	
		4:2:2 10	410	29.97P / 25P 24.0P / 23.98P	40 min	80 min	
	2K (2048x1080) or HD (1920x1080)	4:4:4 12	440	59.94 P / 50P	35 min	75 min	
		4:4:4 12	225	29.97P / 25P / 24.0P / 23.98P	75 min	150 min	
		4:4:4 10	410	59.94P / 50P	40 min	80 min	
		4:4:4 10	210	29.97P / 25.0P / 24.0P / 23.98P	80 min	160 min	
		4:2:2 10	310	59.94P / 50P	50 min	105 min	
		4:2:2 10	160	29.97P / 25.0P / 24.0P / 23.98P	105 min	210 min	
		XF-AVC Long GOP	4:2:2 10	50	59.94P / 50P / 29.97P / 25P / 24.0P / 23.98P 59.94i / 50i	335 min	680 min

9.3 Super 16mm Crop Mode

When a Super 16mm lens or a 2/3-inch broadcast lens (with the B4 mount adapters – MO-4E for EF-mount /MO-4P for PL-mount) is used on EOS C700 FF the recording modes are as shown in Table 3

Table 3 XF-AVC Recording Modes for the Super 16mm Sensor Crop

Codec	Resolution	Color Sampling & Bit Depth	Max Bit Rate (Mbps)	Frame Rates (fps)	Media	CFast
					Recording Duration	
					128 GB	256 GB
XF-AVC Intra	2K (2048x1080) or	4:2:2 10	310 160	59.94P / 50P 29.97P / 25P / 24.0P / 23.98P	50 min 105 min	105 min 210 min
Super 16 mm Crop						
XF-AVC Long GOP	HD (1920x1080)	4:2:2 10	50	59.94 / 50P / 29.97P / 25P / 24.0P / 23.98P 59.94i / 50i	335 min	680 min

10.0 ON-BOARD RECORDING IN INTRA PRORES MODE

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

Table 4 ProRes Recording Modes for Full Frame / S35mm / S16mm Crop

Codec	Resolution	Color Sampling & Bit Depth	Max Bit Rates Mbps	Frame Rates fps	Media	CFast
					Recording Duration	
					128 GB	256 GB
PR 422HQ	4K (4096 x 2160)	4:2:2 10	707 – 940	29.97P	15 min	35 min
	UHD (3840 x 2160)			23.98 / 24 / 25 / 29.97P	20 min	40 min
Full Frame or Super 35mm Crop	2K (2048x1080)	4:4:4 12	629 – 754	50P / 59.94P	25 / 20 min	50 / 40 min
PR 4444	HD (1920x1080)		302 – 377	25P / 29.97P 23.98P / 24 P	50 / 40 min	110 – 85 min
PR 422HQ	2K (2048 x 1080)	4:2:2 10	419 – 503	50P / 59.94P	40 / 33 min	80 / 66 min
	HD (1920 x 1080)				45 / 38 min	90 / 76 min
	2K (2048 x 1080)	4:2:2 10	201 – 251	25 / 29.97P/ 23.98 / 24P	67 min	134 min
	HD (1920 x 1080)				77 min	154 min
PR 422HQ	2K (2048x1080)	4:2:2 10	280 – 335	50P / 59.94P	60 / 50 min	120 / 100min
Super 16mm Crop	HD (1920x1080)				68 / 57 min	136 / 114min
	2K (2048 x1080)	4:2:2 10	131 – 168	23.98 / 24 / 25 / 29.97P	101 min	202 min
PR 422	HD (1920x1080)		245 – 293	168P maximum	115 min 50 min	230 min 110 min

11.0 2.35 : 1 WIDESCREEN WITH SPHERICAL LENS AND FF

The EOS C700 FF offers a widescreen option that entails no anamorphic lens. Rather, a full frame spherical lens is deployed and the camera menu is set for 2.35:1 widescreen readout and a vertical cropping of the photosites is activated according to the dimensions shown in figure 22.

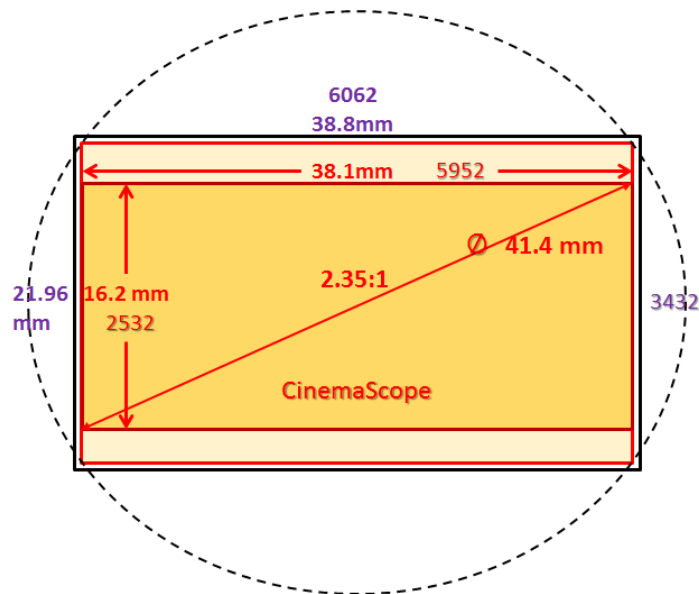


Figure 22 Showing the non-anamorphic image capture for a 2.35:1 aspect ratio

This is a high resolution 5952 (H) x 2532 (V) digital representation of the widescreen image that can be recorded as RGB Bayer RAW in the Codex CDX-36150 recorder.

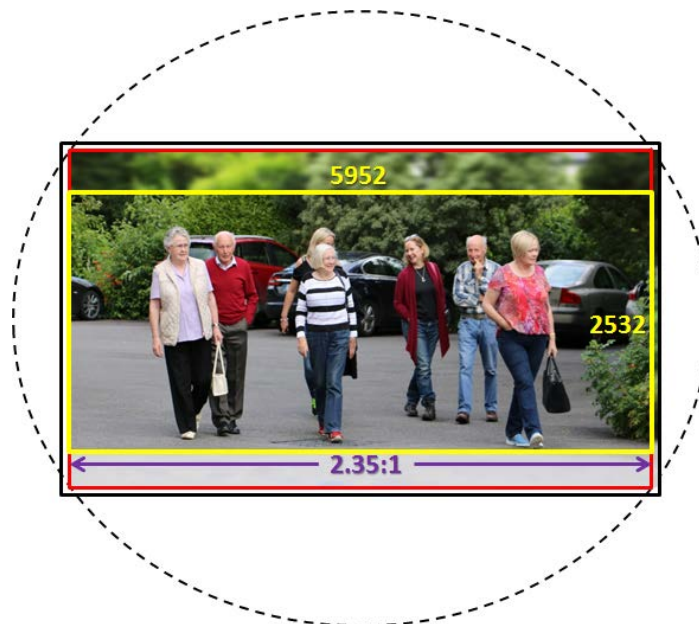


Figure 23 Illustrating the widescreen 2.35:1 image capture readout of the sensor using a spherical lens

12.0 ANAMORPHIC IMAGE CAPTURE IN THE EOS C700 FF

Back in the 1950s when the Hollywood studios experimented with a variety of image presentation systems to try and differentiate cinema viewing from the rapidly rising home television viewing – the drive soon centered on various approaches to widescreen imagery. Anamorphic lens technology was resurrected as a central approach – horizontally compressing an image onto the then standard 4:3 35mm motion picture film. A complementary lens in the cinema projector would unsqueeze the image and a widescreen portrayal was made possible without any need to change cameras, postproduction practices, and projectors. A variety of anamorphic aspect ratios were explored for some years and finally the SMPTE standardized on the 2.39:1 aspect ratio in 1993 (ST 195-1993).

To better understand anamorphic techniques in the age of digital cinema consider the scene below:



Figure 24 Showing a hypothetical scene that is being viewed by a Director and Cinematographer who are contemplating a final 2.39:1 widescreen projection



Figure 25 The creative decision that is made on-set for a framing for the final 2.39:1 projected image

The beauty of the anamorphic lens is that it allows the full height of the image format to be used and avoids any letterboxing – that adds up to increased overall image sharpness. A creative decision is made to use anamorphic lenses having horizontal compression of either 2 x or 1.3 x. We will look at three separate anamorphic modes entailing these two lenses.



Figure 26 *2:1 anamorphic lenses will horizontally compress the image from the lens into the camera*

12.1 Anamorphic Squeeze of 2x 2.39 : 1 Capture with Margins

Many directors and cinematographers prefer to capture a slightly wider compressed image – favoring the use of a 4:3 (or 1.33:1) image capture rather than the 6:5 (1.195 : 1) aspect ratio that defines a precise 2 x squeeze on a 2.39 : 1 ($2.39 / 2 = 1.195$) image format. This practice allows some image margin on either side that will accommodate small repositioning within the postproduction work. This appears to be the more popular contemporary approach today especially in movies and high end television episodics that include VFX imagery. This approach entails an effective input image to the lens having an aspect ratio of $1.33 \times 2 = 2.66 : 1$ as shown in Figure 27.

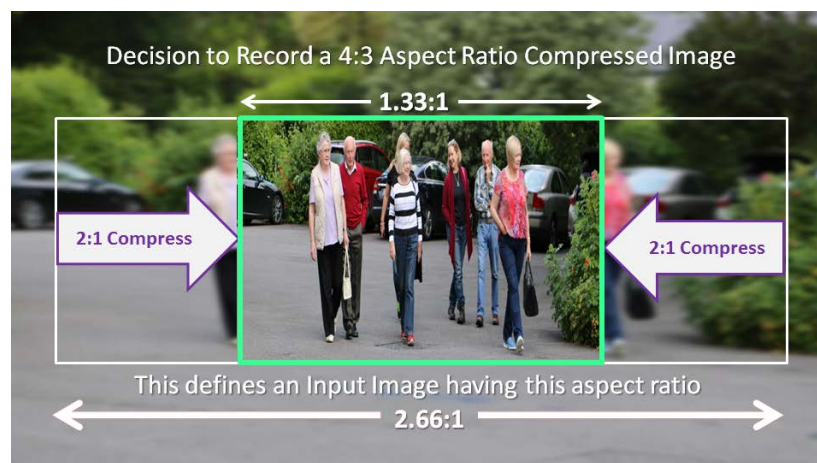


Figure 27 *Desired 4:3 image to be recorded is shown in green while the scene actually framed by the anamorphic 2x cine lens has an effective aspect ratio of 2.66 : 1*

When that image is projected by the 2:1 anamorphic lens onto the full frame image sensor it will appear as in Figure 28. **The camera operators will menu-select the associated vertical framing lines in the EVF** that will guide the accurate scene content selection of that wider 1.33 : 1 compressed image.

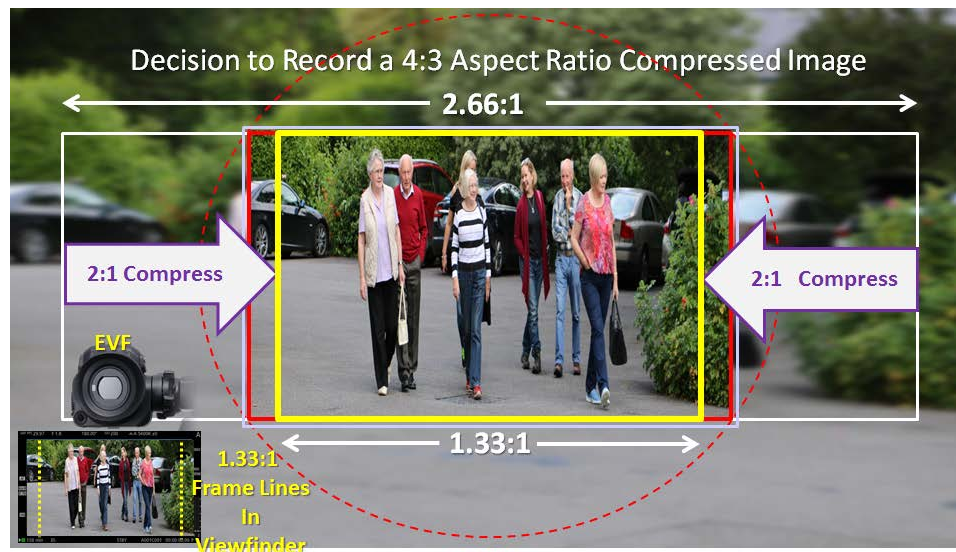


Figure 28 Showing the 4:3 selected image as projected onto the full frame image sensor and the associated 1.33:1 vertical frame lines selected in the EVF

The associated dimensions and photosite sampling of the selected 4:3 image in the full frame image sensor is shown in Figure 29.

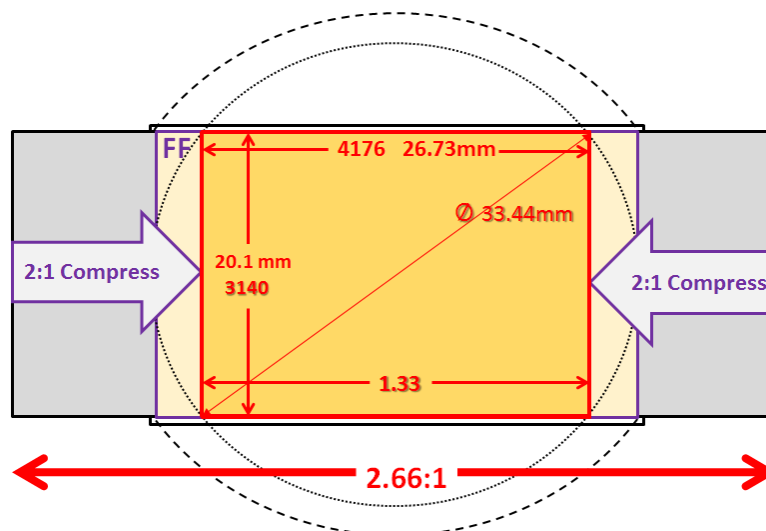


Figure 29 Showing the dimensions and photosite counts (4176 x 3140) for the 1.33 : 1 aspect ratio image

Figure 30 below shows how the 1.33 : 1 image contains the additional image margins that will support modest repositioning of the final desired 6 : 5 content in postproduction.

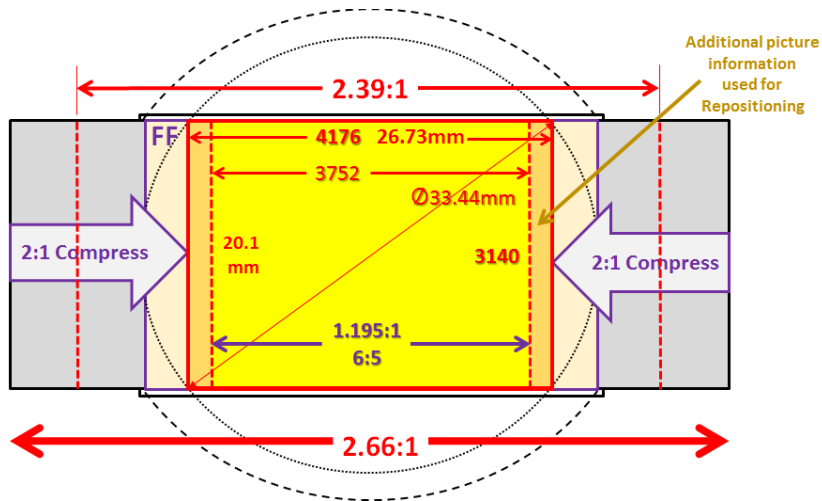


Figure 30 Showing the final 1.195 : 1 (or 6 : 5) deliverable (in yellow) with the repositioning margins on either side – all within the 4:3 captured image

12.2 Recording the 2x Anamorphic Signal

The EOS C700 FF offers significant flexibilities in recording the anamorphic compressed video – a full 5.9K format recorded RAW in the Codex recorder and at the same time a 4K DCI format that has been derived via the *Oversampling 4K Processing* (with enhanced image sharpness and lower aliasing) within the EOS C700 FF can be recorded as YCbCr 4:2:2 @ 10-bit on the CFast2.0 cards using the XF-AVC codec.

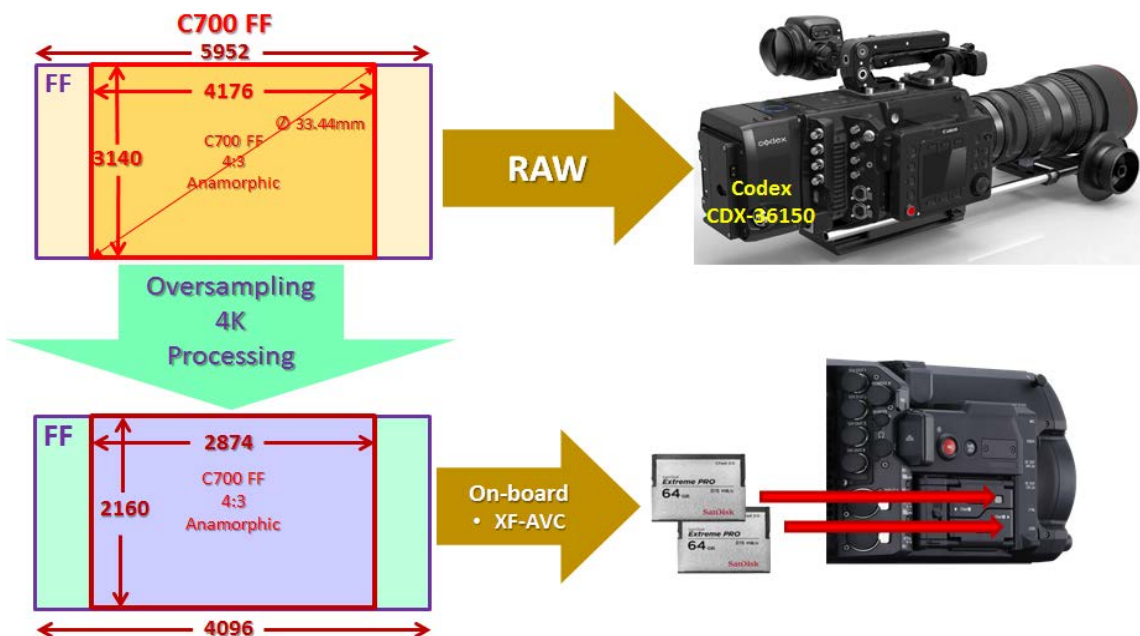


Figure 31 The full 5.9K anamorphic image can be recorded RAW in the Codex recorder while simultaneously a downsampled 4K DCI representation can be recorded on-board on two CFast cards in XF-AVC

12.3 Anamorphic Squeeze of 2 x Precision 2.39:1 Capture

There are two shooting practices currently in use among cinematographers and directors. The first favors precise origination of the 2.39 : 1 final image – without any cropping process. This entails framing of the compressed image in the camera viewfinder to a precise aspect ratio of $2.39 / 2 = 1.195:1$ – which is more typically termed 6 : 5.

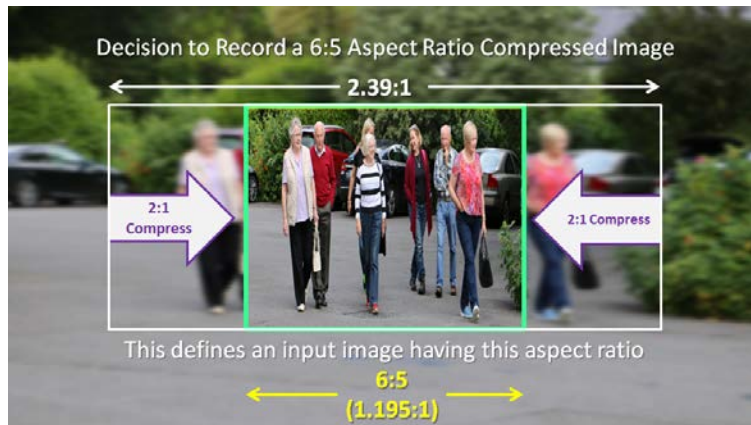


Figure 32 Framing an image that is precisely 2.39 divided by 2 creates a compressed optical image as shown having a 1.195 (or 6:5) aspect ratio

When the anamorphic lens projects that selected image on to the full frame sensor of the EOS C700 FF it will appear as shown in Figure 33. In this case, the cinematographer selects the 6 : 5 (or 1.195 : 1) vertical frame lines in the viewfinder to guide that desired framing of that compressed image.

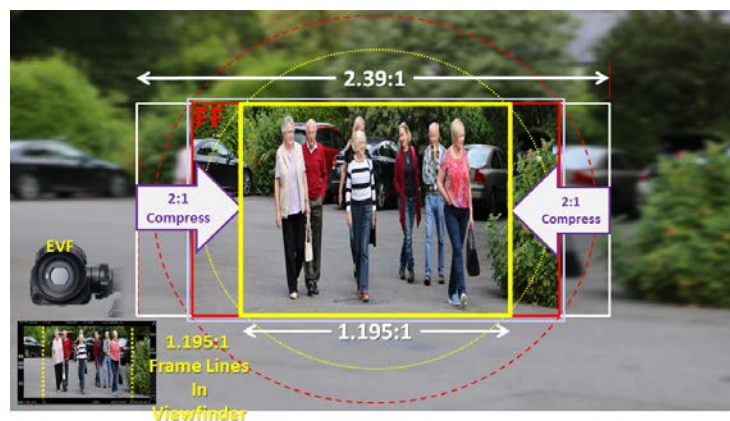


Figure 33 Showing the image projected on to the 17:9 aspect ratio 5.9K full frame image sensor in the EOS C700 FF

The entire 1.896 : 1 sensor can be recorded as RGB Bayer RAW up to 60fps in the Codex CDX-36150 recorder, and then debayered into the 2.39 : 1 stretch and extraction utilizing Canon's Cinema RAW Development Software. Alternatively, the signal can be recorded on-board as a downsampled 4K representation in either XF-AVC or ProRes. During shooting the viewfinder can invoke a precise 2:1 desqueeze mode that allows the 2.39:1 image to be letterboxed for viewing.

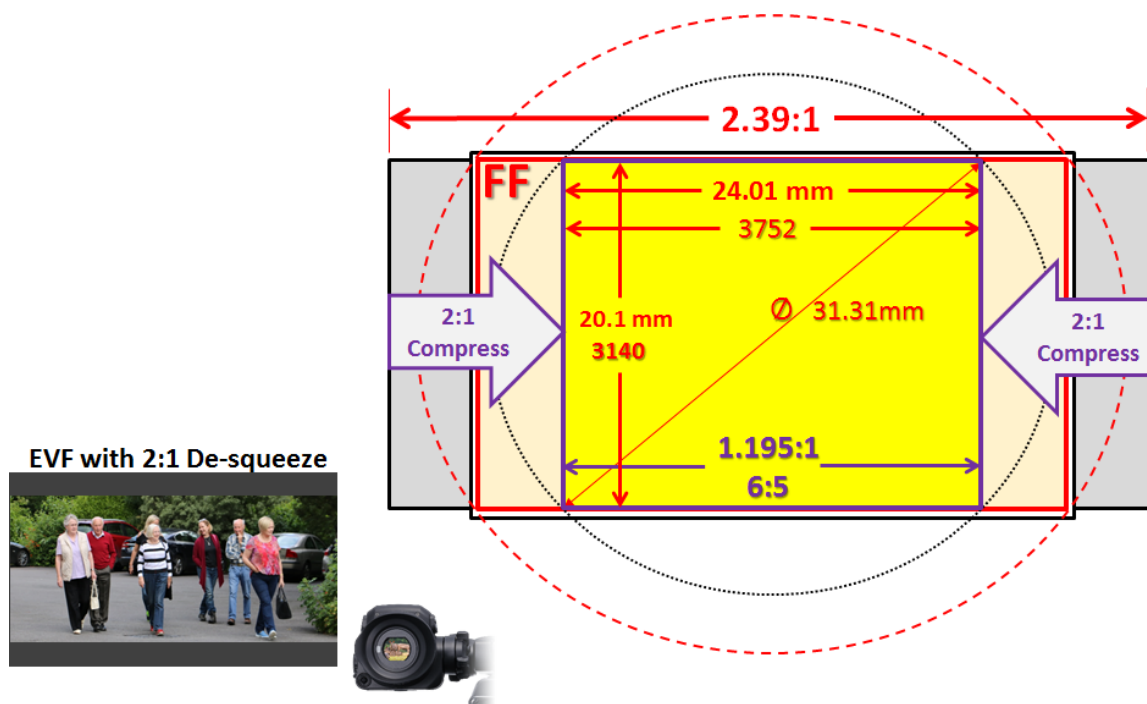


Figure 34 Showing the dimensions and photosite counts for the 1.195:1 aspect ratio image

EOS C700 FF utilizes the *Oversampling 4K Processing* to create a downsampled 4096 (H) x 2160 (V) digital representation of the full frame image that can be recorded on-board using either the XF-AVC or the ProRes codecs. For the 1.195:1 aspect ratio portion it will be noted that the original photosite sampling is 3752 (H) x 3140 (V). However, it is important to note that the resultant elevated MTF and reduced aliasing of this innovative downsampling provides very high overall image sharpness for that desired anamorphic image.

12.4 Anamorphic Squeeze of 1.3x Hi-Res 2.39:1

The 1.3x compression anamorphic lens was developed more recently – specifically to accommodate the wider 1.896 : 1 (17:9) aspect ratio specified by DCI that defines many digital camera image sensors. That lesser degree of compression means that the squeezed image that is sampled and recorded is very close to that DCI aspect ratio ($2.39 / 1.3 = 1.84 : 1$). This works especially well with the full frame sensor as it has more height than the legacy Super 35mm film (20.1 mm versus 18.67 mm). For many this is a preferred approach as it utilizes almost all of the photosites on the image sensor and hence there is a significant gain in horizontal resolution. The FF signal can be recorded as RGB Bayer RAW in the Codex recorder.

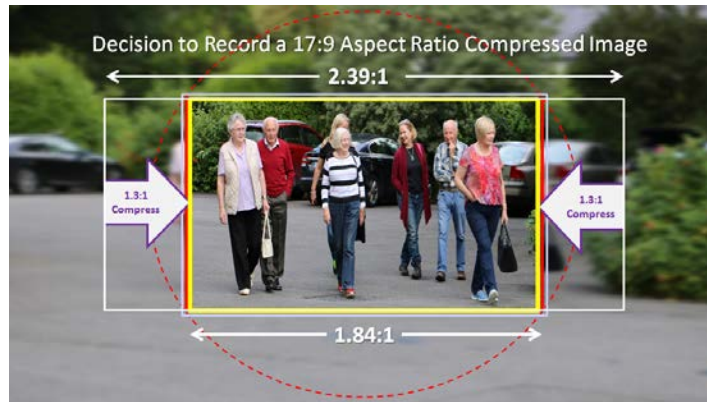


Figure 35 Assuming a full frame anamorphic lens having a squeeze factor of 1.3:1 the compressed image would effectively occupy the total 5.9K full frame sensor

This 1.3 x anamorphic mode in the eOS C700 FF supersamples the compressed image at full 5.9K and this can be recorded RAW in the Codex recorder. Separately, the *Oversampling 4K Processing* will produce a 4K rendition that can be recorded on board in XF-AVC or ProRes – producing a full 4K digital representation having high MTF and minimized aliasing. For those who may not want to use RAW recording this will be an important alternative.

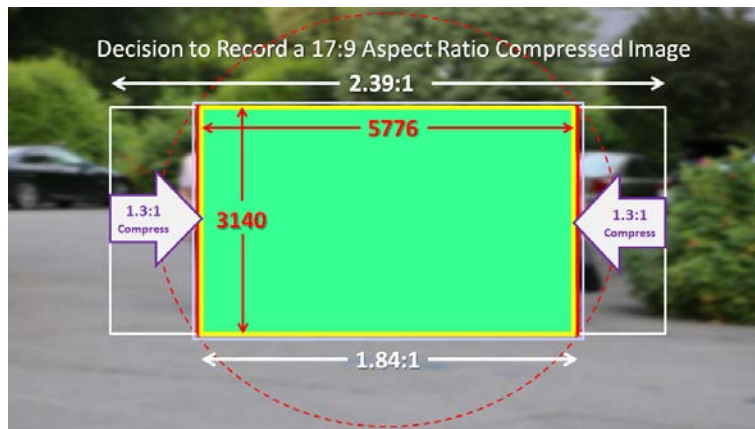


Figure 36 The 1.3:1 anamorphic mode utilizes almost all of the photosites of the full frame imager

The creative community in general favors anamorphic 2 x because of the unique “look” it can impart – the special flares and the oval bokeh etc. However, with the advent of HDR there may be certain scenes that seek to fully exploit this new imaging enhancement in the highlights by minimizing optical artifacts. In such cases, the anamorphic 1.3 x may offer important flexibilities.

It should be noted, however, that at this juncture the availability of full frame 1.3x anamorphic lenses is limited. The HAWK 65 anamorphic 1.3 x prime lenses are one of the few that have an image circle that covers full frame.

Recording the 1.3 : 1 anamorphic utilizes almost the full resolution of the full frame image sensor and thus offers a very high performance RAW recording. The downsampled version utilizes the full 4K DCI resolution and can be recorded as YCbCr 4:2:2 @ 10-bit in XF-AVC or ProRes.

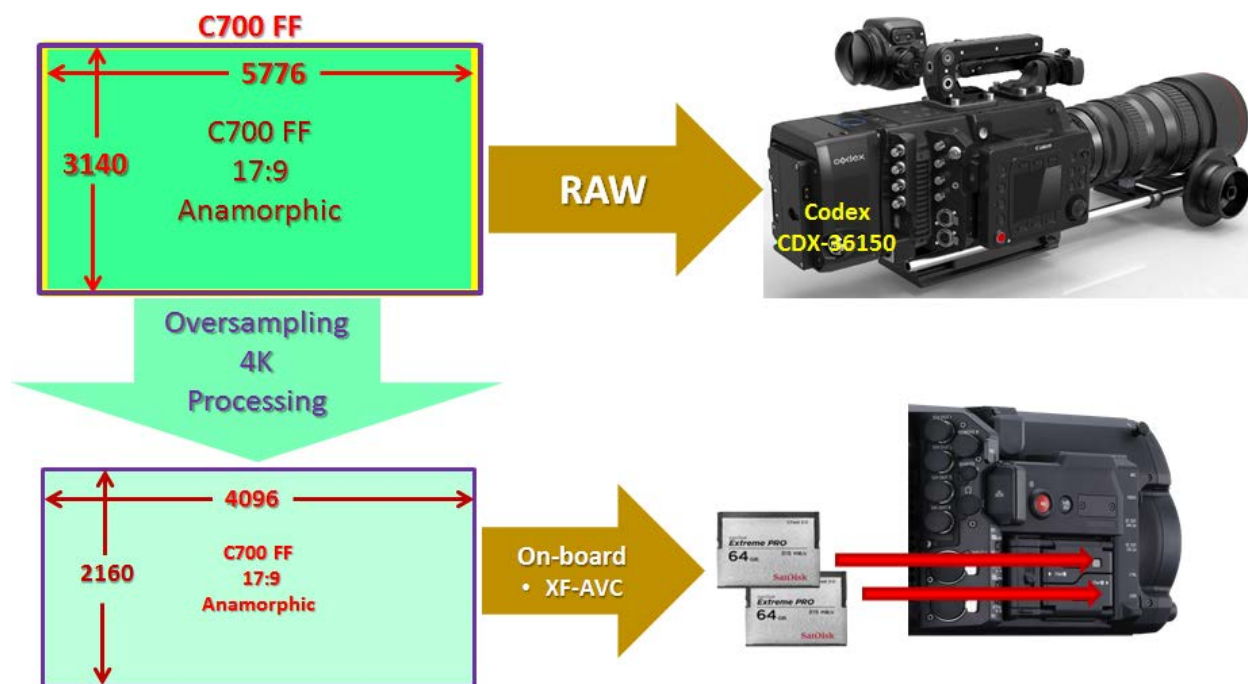


Figure 37 The 1.3 :1 anamorphic lens is ideally suited to the 17:9 aspect ratio of the C700 FF image sensor

NOTE: For all of the anamorphic modes described – if RAW recording of them is not entailed then the EOS C700 FF offers on-board recording using either the XF-AVC or the ProRes codec. If RAW recording is entailed then only the XF-AVC codec can be used for a parallel on-board recording.

12.5 New Full Frame 1.5x Anamorphic Lenses by P+S Technik

The relatively recent arrival of Full Frame digital cinema cameras has spurred fast-paced lens developments from a significant number of optical manufacturers. Recognizing that 2 x anamorphic lenses for Full Frame imagers will be large and heavy, P+S Technik launched a modern, full frame version of the famous Technovision anamorphic lenses, at NAB 2018. They cover Full Format with a 1.5x anamorphic squeeze. This stronger compression factor offers optical characteristics more akin to those of the 2 x anamorphic lenses. The new Technovision Classic anamorphics are specifically designed to cover larger camera sensors having 1.896:1 aspect ratio such as Canon EOS C700 FF. The aspect ratio of the desired active image will be $2.39 / 1.5 = 1.59$ as shown in Figure 38 and 39.

The Technovision Classic Series includes 2 zoom lenses (35-70, 70-200) and 5 primes (40, 50, 75, 100 and 135 mm).

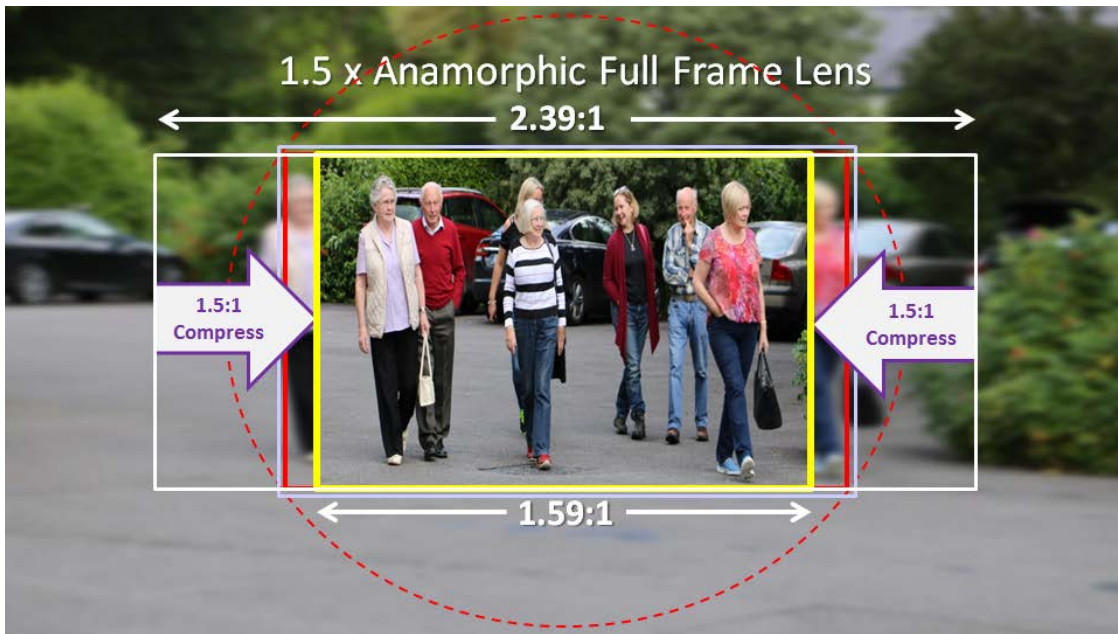


Figure 38 Showing the 1.5 x compressed image as projected on to the 17:9 image sensor

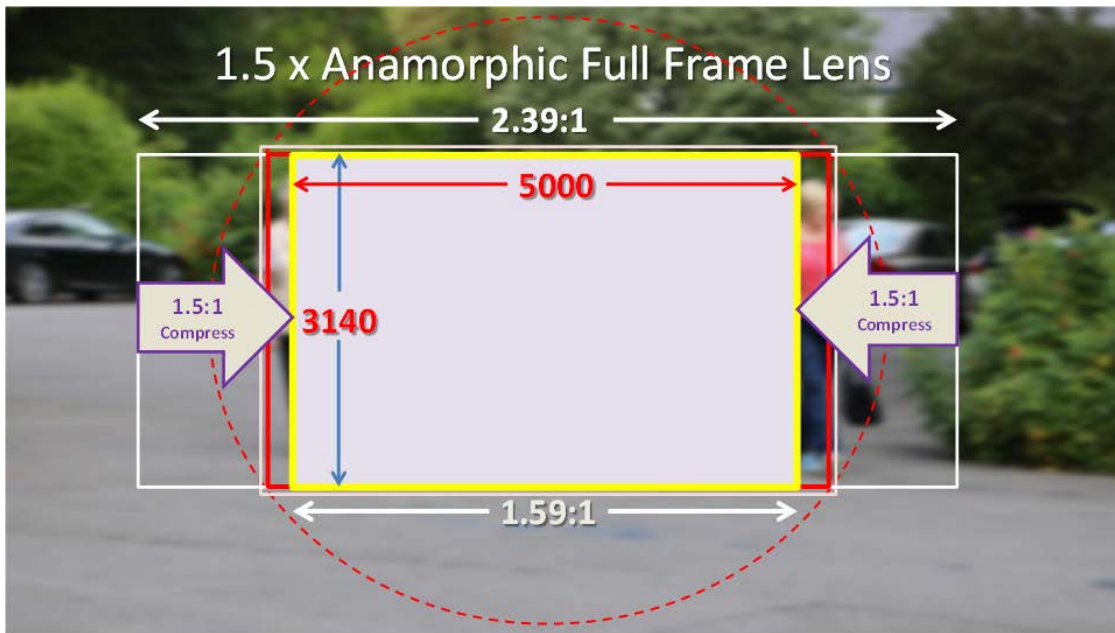


Figure 39 Showing the active photosite count for the RAW image using 1.5 x anamorphics

When downsampled to the 4K container format, the compressed active image structure is 3440 x 2160 that benefits from the sophisticated *Oversampling 4K Processing* described in this paper.

13.0 SUMMARY

The EOS C700 FF offers important new levels of image performance and creative flexibilities. In combination with full frame cine lenses the large full frame image sensor supports capture of 2.1 times more scene content than is possible with a Super 35mm lens *set to the same focal length*.

Canon specifically chose a 17:9 aspect ratio for the active image area of the image sensor – *while still preserving the traditional image circle diameter of 43.1 mm of the 1.5:1 full frame format*. There is no image cropping when a full frame lens is employed. This, because the priority of the EOS C700 FF is digital motion imaging – intended to meet the 4K and 2K (with 17:9 aspect ratio) digital deliverables specified by the major studio DCI specification. The separate television standardized deliverables of 16:9 aspect ratio 4K UHD and HDTV are also comfortably accommodated within this format. The biggest advantage of this image sensor decision is:

1. ALL of the sensor photosites are activated in originating the 17:9 DCI image format
2. WIDER image (than that originated by a 1.5: 1 image sensor) is inherent to the 17:9 format

The 5.9K image sensor resolution holds promise of superb image quality – provided the operational challenges of lens focusing are overcome. The Dual Pixel CMOS Auto Focus is a powerful assistance in shooting situations entailing high mobility. Equally important, the same technology latent within this image sensor empowers accurate signaling in the viewfinder as to when a manual focus operation has reached precision focus – a mode of operation termed Focus Guide. That signaling indicates *the direction of manual focus rotation required to seek precise focus on a chosen subject* within a scene (a moveable viewfinder cursor is positioned on that subject).

The innovative *Oversampling 4K Processing* within the EOS C700 FF structures a 4K digital format that has enhanced MTF, lower aliasing, and lower noise than is possible with traditional native 4K origination. On board recording in either XF-AVC or ProRes is a major advantage of the EOS C700 FF.

As described in the paper the anamorphic lens possibilities with the EOS C700 are truly extensive.

14.0 REFERENCES

[1] White Paper “*Extended Recording Capabilities in the EOS C700 Camera*”
<https://downloads.canon.com/nw/camera/products/cinema-eos/c700/white-papers/eosc700-whitepaper-extended-recording.pdf>

[2] Film&Digital Times, June 2018 Pages 70-71 “*Technovision Classic 1.5x Anamorphic Full Frame Lenses by P+S Technik*”
<https://www.fdtimes.com/issues/new-edition-cine-gear-2018/>

15.0 APPENDIX DETAILS ON OVERSAMPLING 4K PROCESSING

This appendix is intended to demonstrate the technical advantages of the *Oversampling 4K Processing* used within the EOS C700 FF to create an enhanced 4K representation of what was imaged at 5.9K resolution in the camera image sensor.

All testing was done with a circular zone plate test chart having 6 sinusoidal modulated patterns – see Figure below. The six patterns explore Luma (in the center) and Chroma channels on the bottom row, and individual RGB channels on the top row. This examination allows a scrutiny of how resolution falls off and how aliasing may or may not contaminate both Luma and Chroma. If they exist, alias patterns will be evident as sets of concentric modulation centered away from the true center of the pattern. The centers of any alias patterns will be visible as ‘null zones’ at frequencies defined by the sampling structure of the sensor. This is considered incontrovertible evidence of the sensor resolution.



Figure 40 4K Test Chart that facilitates Examination of Luma and Chroma Resolution and Aliasing

We discovered that effective showing of the resolution enhancement is not possible due to the compression of the PDF process and the limitation of the printed page. However, we are able to very visibly reproduce the significant reduction of aliasing due to this innovative Canon processing.

The first three of the succeeding pages show the truly excellent control of aliasing in each of the red, green, and blue video components in the EOS C700 FF. The fourth page illustrates the reduction of aliasing in the Luma signal.

NOTE: To effectively convey the test results in imagery that can be viewed on a computer or on a printed page we have made the test images large in the following pages. ***To obtain a reasonably accurate representation of the actual performance it is recommended that the pdf be elevated to 300% magnification for viewing.***