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WHITE PAPER

EOS C300 MARK II

EXTENDED RECORDING CAPABILITIES IN THE EOS C300 MARK II

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CINEMA EOS

Extended Recording Capabilities in the EOS C300 Mark II

Abstract

The original EOS C300 was introduced in November 2011. It uses a 4K single image sensor to exclusively originate 1920 x 1080 HD [1]. It records this on-board using an MPEG-2 codec operating 8-bit YCrCb 4:2:2 @ 50 Mbps. It simultaneously delivers an uncompressed 8-bit YCrCb 4:2:2 output via an HD SDI port. Three years later the second generation Cinema EOS system is making its debut. The EOS C100 Mark II was introduced in the latter half of 2014 and now the EOS C300 Mark II has made its debut at NAB 2015.

The new C300 Mark II camcorder offers significantly elevated video performance and expanded operational capabilities. Unlike its predecessor, the C300 Mark II offers a choice of 2K or HD. Most important, it greatly extends on-board recording capabilities by deploying a new codec based upon the more advanced MPEG-4 H.264 Advanced Video Coding (AVC) compression algorithm. Canon's implementation of this codec is called XF-AVC. In the 2K / HD mode it can record RGB 4:4:4 at 12 or 10-bit at frame rates up to 29.97 fps progressive. It can record YCrCb 4:2:2 at 10-bit with frame rates up to 59.94 fps progressive. It does all of this recording at far higher data rates than the 50 Mbps of the earlier C300. In addition, the C300 Mark II offers a choice of 4K or UHD origination and recording using the XF-AVC codec at a very high bit rate at frame rates up to 29.97 fps progressive. Finally, the camcorder offers alternative uncompressed 10-bit 4K / UHD RAW or 2K / HD component video outputs via a 3G SDI terminal for external recording.

1.0 Introduction

The original EOS C300 represented Canon's definitive entry into the digital cinematography marketplace. While largely television-centric and comparatively modest in its recording capabilities it quickly established a worldwide reputation for excellent image quality, ergonomics that favored handheld shooting, unusually high sensitivity, and very low power consumption. These attributes made it a favorite among global documentary shooters. MPEG-2 remains a central recording format to much of the broadcast television world. The 8-bit Long GOP format (operating at either 50 Mbps or 35 Mbps) is central to the workflow efficiencies sought by broadcast program production for fast-breaking news, live sporting events, long-form documentary production – where the relatively small file size is enormously beneficial to associated storage constraints, transmission needs, and economies in editing and computational needs. This codec will likely remain popular for some time.

The C300 was designed in concert with a family of Super 35mm cine zoom and prime lenses [2] – a design strategy that did much to optimize the picture qualities of the Cinema EOS combined lens-camera system. Much was learned from the extensive shooting experiences of the many who acquired the C300 system. Both favorable and critical commentaries were carefully gathered over the past three years and they significantly influenced the multiple design decisions that were to shape the successor C300 Mark II.

The central goal of the new C300 Mark II is to substantially bolster on-board recording capabilities while also enhancing the image performance of the camera section. This would take into account ongoing aspirations for improved HDTV performance while also squarely addressing the needs of digital cinematography for theatrical motion picture production. Accordingly, this new design placed the highest priority on two key advances beyond the C300:

a) The need for much higher recording capabilities for 1080-line HD and to also accommodate the standardized 2K digital cine format

b) To also support the slowly emerging use of 4K and UHD recording

The past few years have seen the rapid adoption of the MPEG-4 compression algorithm as the basis for a variety of new high-end recording codecs. Canon mobilized this compression algorithm as the basis for their development of the new XF-AVC codec that is central to the C300 Mark II.

2.0 XF-AVC Codec

XF-AVC is a compressed digital format specially developed by Canon to achieve the highest level of overall video performance for on-board recording. It uses the well-established MXF file format as its container, and is fully compliant with the MPEG-4 Advanced Video Coding (AVC)/H.264 compression algorithm [3]. For a given bit rate, this algorithm achieves approximately twice the compression ratio as MPEG-2 codec while maintaining the same picture quality. Anticipating the increasing use of higher bit depths, higher frame rates, and higher overall data rates to significantly elevate overall video performance this codec plays a pivotal role within our evolving second generation Cinema EOS system. It also anticipates the growing adoption of IP-based infrastructures and cloud-based networks.

XF-AVC complies with H.264 Level 5.2 which encapsulates the video essence within an industry standardized wrapper known as the MXF OP-1a file format. The XF-AVC codec encompasses the use of both Intra-frame and Inter-frame Long-GOP formats to offer wide choices in recording data rates and associated recording durations.

3.0 XF-AVC in the Context of the Larger Contemporary Marketplace

Advanced Video Coding (AVC H.264) has been adopted by most of the major established manufacturers of high end professional content creation products. Because of this adherence to a global unified standard most will incorporate the “AVC” within the individually unique logo identifiers used on their respective products.

- In 2007 – Panasonic introduced a line of professional HD camcorders using their implementation of a codec based upon AVC/H.264 – formally termed ***AVC-Intra***

- In 2012 – Panasonic elevated the level of their AVC-based codecs in anticipation of 4K camcorders and even higher levels of HD and 2K. They term this coded ***AVC-Ultra.***

- In 2012 – Sony introduced their new codec based upon AVC/H.264 – also in support of higher levels of HD / 2Kand UHD /4K. They identify this codec as this ***XAVC***

- In 2015 – Canon is introducing our own unique implementation of the AVC/H.264 codec – we call it ***XF-AVC.***

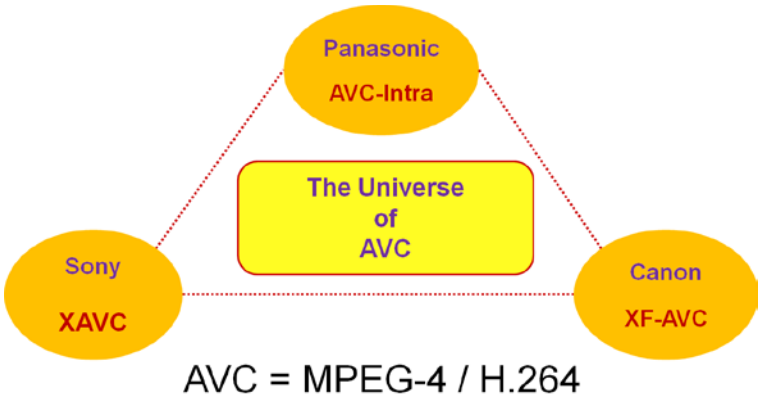


Figure 1 *The MPEG-4 Advanced Video Coding compression algorithm has become central to contemporary high-end recording for 2K / HD and 4K / UHD*

The EOS C300 Mark II is intended to support far higher digital motion imaging capture than was possible with the original EOS C300. This would entail recording at:

- Far higher data rates than is possible with MPEG-2
- Higher bit depths than the 8-bit of MPEG-2
- 4:4:4 component coding in addition to the 4:2:2 of MPEG-2
- Higher picture capture rates than 29.97P and 59.94i

4.0 Three levels of XF-AVC deployed in the EOS C300 Mark II

To encompass the broad range of recording choices planned for the C300 Mark II three separate levels of the XF-AVC codec are available. XF-AVC-Intra is the upper level of this hierarchy. Intra-frame coding refers to the fact that the compression techniques that are mobilized are performed relative to information contained within a single current frame, and has no relationship with any other frame in the video sequence. In other words, no temporal processing is performed outside of the current picture or frame.

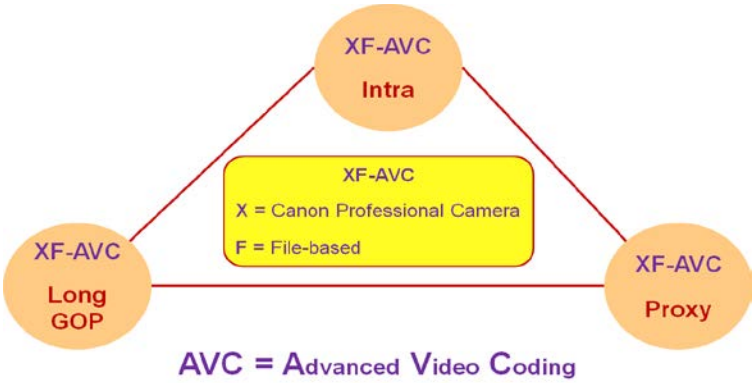


Figure 2 *Showing the three levels of compression strategies within the AVC standard that are* used in the C300 Mark II

4.1 Intra XF-AVC Mode – *Maximum Image Quality for HD / 2K*

This is the recording mode that supports exceptionally 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 1. 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.

TABLE 1 High-end Intra-frame recording of **RGB 4:4:4** for 1080-line 2K and HD

Format	Codec	Resolution	Color Sampling Bit Depth	Frame Rates	Max Bit Rate	Wrapper	VBR CBR
2K	**H.264 Intra**	2048 x 1080	444 12-bit 444 10-bit	23.98 / 24.0 /25.0 / 29.97P	225 Mbps @ 29.97P 210 Mbps @ 29.97P	MXF	VBR
HD	**H.264 Intra**	1920 x 1080	444 12-bit 444 10-bit	23.98 / 24.0 / 25.0 / 29.97P	225 Mbps @ 29.97 210 Mbps @ 29.97P	MXF	VBR

Because of the priority given to maximizing the recording data rate for the 12-bit 4:4:4 video component set the maximum frame rate is limited to 29.97 fps progressive.

TABLE 2 High-end Intra-frame recording of **YCrCb 4:2:2** for 1080-line 2K and HD

Format	Codec	Resolution	Color Sampling Bit Depth	Frame Rates	Max Bit Rate	Wrapper	VBR CBR
2K	H.264 Intra	2048 x 1080	422 10-Bit	50 / 59.94P 23.98 / 24 /25 /29.9 P 120 / 119.88 / 100P	310 Mbps 160 Mbps 550 Mbps	MXF	VBR
HD	H.264 Intra	1920 x 1080	422 10-bit	50 / 59.94P 23.98 /24 / 25 / 29.97 P 50 / 59.94i 120 / 119.88 / 100P	310 Mbps 160 Mbps 160 Mbps 550 Mbps	MXF	VBR

Here the three components are encoded to YCrCb 4:2:2 at 10-bit – and now for almost the same recording data rate the picture capture rates can extend as high as 59.94 fps progressive.

4.2 XF-AVC Long GOP – *for HD/2K Broadcast Television Applications*

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 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 3 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

4.3 XF-AVC Proxy – *Low Data Rate Proxy for Offline Editing*

To support offline editing of any of the above HD / 2K / UHD / 4K formats, the C300 Mark II 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 5, the recording data rate varies from 24 Mbps to 35 Mbps depending upon the frame rate.

TABLE 4 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
				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 24 Mbps		

5.0 Intra XF-AVC Mode – *Maximum Image Quality 4K / UHD*

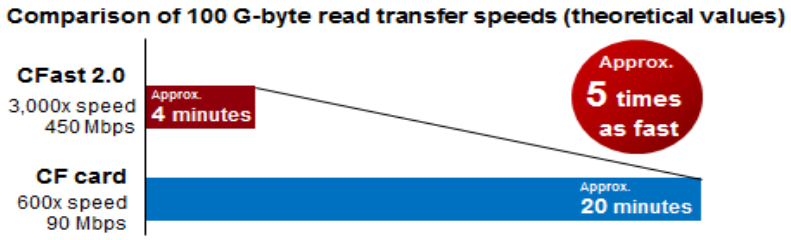
In addition to its greatly extended on-board recording capabilities for both HD and 2K, the EOS C300 Mark II can, in addition, also record either UHD or 4K at picture capture rates of 23.98 / 24.0 / 25.0 / 29.97 fps progressive. While this frame rate is modest in an era that is showing increasing interest in Higher Frame Rate (HFR), this recording is coded YCrCb 4:2:2 at 10-bit, which, combined with the very high bit rate of 410 Mbps ensures quite superb capture of overall 4K image quality.

TABLE 5 High-end Intra-frame recording of **YCrCb 4:2:2** 2160-line 4K and UHD

Format	Codec	Resolution	Color Sampling Bit Depth	Frame Rates	Max Bit Rate	Wrapper	VBR CBR
4K	H.264 Intra	4096 x 2160	422 10-bit	23.98 / 24.0 /25.0 / 29.97P	410 Mbps @ 29.97P	MXF	VBR
UHD	H.264 Intra	3840 x 2160	422 10-bit	23.98 / 24.0 / 25.0 / 29.97P	410 Mbps @ 29.97P	MXF	VBR

6.0 Recording Media

The recently standardized CFast (2.0) memory card was selected as the primary recording media for the C300 Mark II because of its exceptionally high transfer speed. In the case of the SanDisk Extreme Pro card, high-speed transfer is possible at a read speed of up to 450 MB/sec. (3,000x speed) and a write speed of up to 225 MB/sec. (1,500x speed).



Utilizing this latest in standardized media has the following advantages:

- Avoids the uncertainties of proprietary media cards
- Certainty that as global volume of these standardized cards inexorably grows their costs will steadily lower (just as it did with Compact Flash cards)
- Worldwide availability

Extreme PRO CFast2.0 Memory Card	SDCFSP-128G-xxxA	128GB
	SDCFSP-64G-xxxB	64GB
	SDCFSP-128G-xxxB	128GB

Figure 3 *Showing one example of the newly standardized CFast (2.0) memory cards*

7.0 Recording Durations

The C300 Mark II offers extended recording durations depending upon the capacity of the recording media. Utilizing two CFast cards allows the choice of parallel recording (for backup) or relay recording that doubles the recording durations listed in Table 6.

TABLE 6 XF-AVC INTRA CODEC RECORDING DURATIONS

Format	Color Coding	Bit Depth	Bit Rate (Mbps)	Frame Rates (fps)	Media Cfast (GB)	
					128	256
4K / UHD	4:2:2	10	410	29.97P / 25P 24.0P / 23.98P	40 min	80 min
2K / HD	4:2:2	10	550	119.88P / 100P	30 min	60 min
	4:2:2	10	310	59.94P / 50P	50 min	105 min
	4:4:4	12	225	29.97P / 25P	75 min	150 min
		10	210	24.0 / 23.98P	80 min	160 min
	4:2:2	10	160	29.97P / 25P 24.0P / 23.98P	105 min	210 min

TABLE 7 XF-AVC LONG GOP CODEC RECORDING DURATIONS

Format	Color Coding	Bit Depth	Bit Rate (Mbps)	Frame Rates (fps)	Media Cfast (GB)	
					32	64
XF-AVC Long GOP Broadcast	4:2:2	10	50	59.94P / 50P	80 min	160 min
				29.97P / 25P 24.0 / 23.98P 59.94i / 50i	80 min	160 min

Format	Color Coding	Bit Depth	Bit Rate (Mbps)	Frame Rates (fps)	Media SD Card (GB)	
					16	32
XF-AVC Proxy	4:2:0	8	35	59.94P / 50P	60 min	120 min
			24	29.97P / 25P 24.0P / 23.98P 59.94i / 50i	85 min	175 min

8.0 RAW Recording

While the C300 Mark II is recording either 4K or UHD on-board via the XF-AVC codec, it simultaneously delivers an uncompressed 10-bit Log encoded RAW version of that selected format via the 3G SDI output terminal labeled REC OUT. It also delivers the same signal on the MON 3G SDI output terminal. That 4K RAW signal is prepared in an identical manner to the RAW output of the EOS C500 camera. The four separate high-bit depth R, Gr, Gb, B 4:4:4:4 video components are read out in parallel from the image sensor at a high bit-depth and are mapped to the 10-bit Canon Log2 OETF prior to multiplexing into the serial 3G SDI RAW output. A 1920 x 1080 HD version is made available on the HDMI output terminal.

If the C300 Mark II is set for XF-AVC Intra internal recording of 2K / HD RGB 4:4:4 @ 12 or 10-bit then that same signal – in uncompressed 10-bit log encoded form – is available on the REC output terminal, while a YCbCr 4:2:2 10-bit version is available on the MON output terminal.

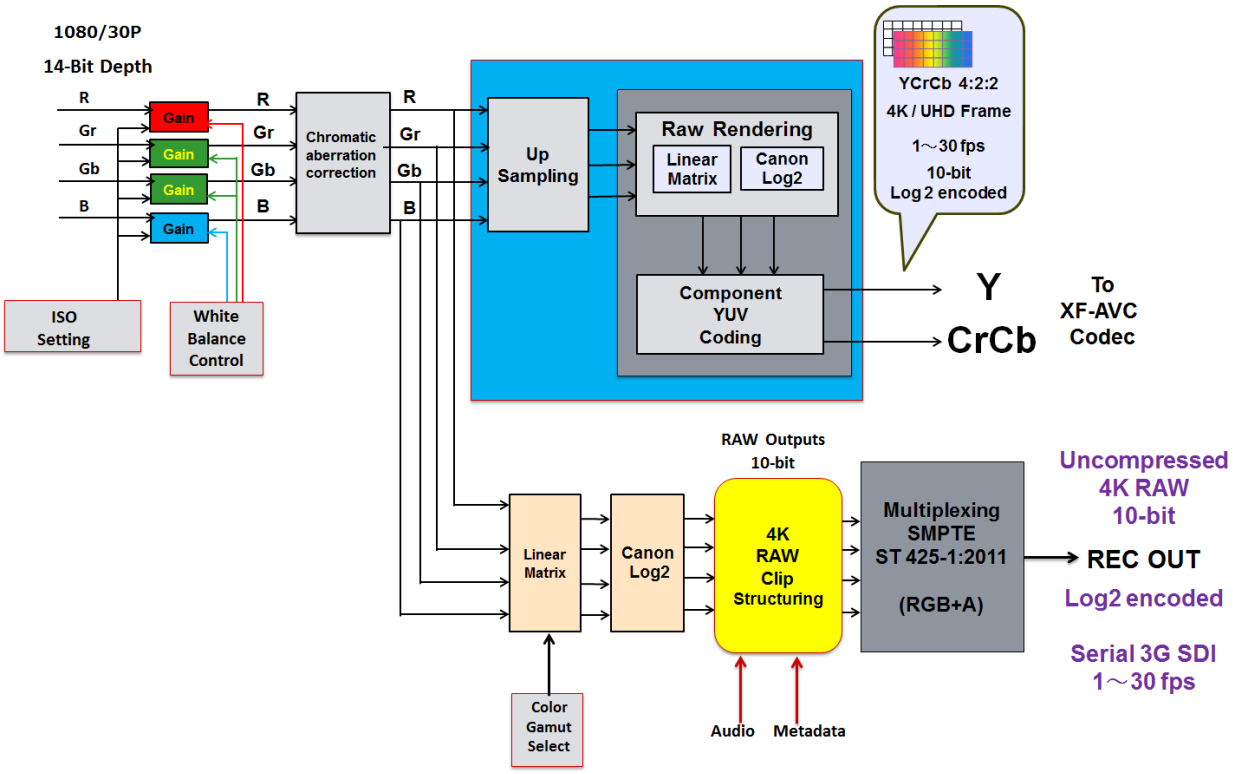


Figure 4 *Showing the parallel formation of the uncompressed 4K RAW signal output*

Figure 5 *Showing the two CFast cards for on board recording and the two RAW outputs for external recording*

9.0 Slow and Fast Motion Recording

The C300 Mark II can be set to shoot and capture at a wide range of frame rates. It can be set in 1 fps increments from 1 to 30 fps, in 2fps increments from 32 to 60 fps, and in 4 fps increments from 60 to 120 fps. Depending upon the choice of recording farme rate and the separate choice of the playback frame rate the C300 mark II can implent either Fast Motion playback (over quite a broad range) or alternatively Slow Motion Playback (over a more modest range) . Table 7 outlines all of the choices when the camcorder is operating in either the 2K or the HD mode. It should be noted that proxy recording during Fast and Slow Motion is not possible at recording frame rates greater than 59.94P.

Table 8 Slow and Fast Motion Recording for 2K / HD in the C300 Mark II

Recording frame rates (Up to 30 fps in 1 fps increments, up to 60 fps in 2 fps increments and up to 120 fps in 4 fps increments

2K / HD Recording Frame Rates		1 → 24	25	30	50	60	100 → 120
2K / HD Playback Frame Rates	59.94P	60x	2.5x	2.4x	2.0x	1.2x	100% Standard	0.50x
	50.00P	50x	2.08x	2.0x	1.66x	100% Standard	0.83x	0.50x
	29.97P	30x	1.25x	1.2x	100% Standard	0.6x	0.50x	0.25x
	25.00P	25x	1.04	100% Standard	0.83	0.50x	0.42x	0.25x
	24.00P	24x	100% Standard	0.96x	0.80	0.48x	0.40x	0.20x
	23.98P	24x	100% Standard	0.96x	0.80	0.48x	0.40x	0.20x

The Green shaded area shows the Slow Motion choices and the Blue shows the Fast Motion choices

For the 4K / UHD recording mode the maximum recording frame rate of 29.97 fps limits the range of Slow and Fast Motion recording options compared to those of the 2K / HD recording mode.

Table 9 Slow and Fast Motion Recording for 4K / UHD in the C300 Mark II

Recording Frame Rates (Up to 30 fps in 1 fps increments)

4K / UHD Recording Frame Rates		1 → 24	25	30
4K / UHD Playback Frame Rates	29.97P	30x	1.25x	1.20x	100% Standard
	25.00P	25x	1.04x	100% Standard	
	24.00P	24x	100% Standard	0.96x	0.80x
	23.98P	24x	100% Standard	0.96x	0.80x

The Green shaded area shows the Slow Motion choices and the Blue shows the Fast Motion choices

10.0 Audio Recording

The original C300 has two channels of 16-bit / 48KHz audio. The new C300 Mark II supports four channels of LPCM 24-bit / 48 kHz audio (which is superior to CD sound quality). A 16-bit alternative can also be selected.

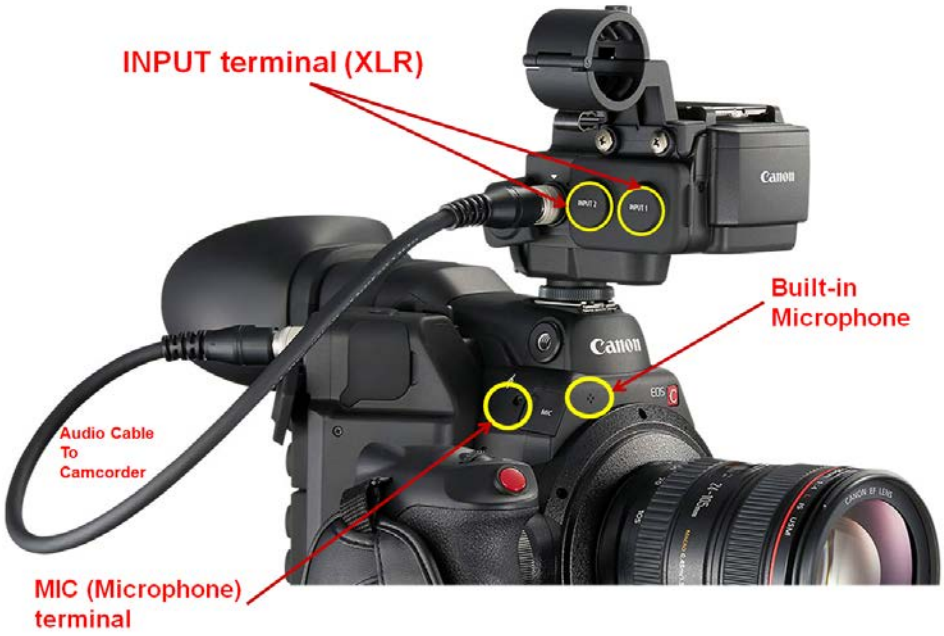


Figure 6 *Showing the four separate audio inputs to the C300 Mark II*

Linear pulse code modulation (LPCM) is a method for digitally encoding uncompressed sampled analog audio information where the quantization levels are linearly uniform. It is the basis for most contemporary high performance audio recording formats.

11.0 Summary

The C300 Mark II represents a very significant advance over the first generation C300 in terms of its on-board recording capabilities.

The combination of the exceptional enhancements to the camera output image quality and the far more broad recording options make the C300 Mark II a preeminent 2K / HD acquisition system. A separate white paper outlines the many technologies mobilized to enhance the overall image quality [4]. A 15-stop HDR dynamic range, wide color gamuts, up to 12-bit depth, 4:4:4 color sampling, and high progressive frame rates collectively produce 2K / HD imagery of stunning quality. Capturing all of that quality via on-board recording was a central imperative to the C300 Mark II design. As outlined in this paper this is accomplished with a globally standardized MPEG-4 H.264 high efficiency codec operating at exceptionally high data rates.

Finally, what thrusts the C300 Mark II way above the C300 is the additional capability of also producing and recording 4K or UHD with a high-performance codec operating at the very high bit rate of 410 Mbps. While the frame rates are limited to 23.98 / 24.0 / 25.0 / 29.97P this will still cover quite a range of productions in both the moviemaking and the television world.

The 4K / UHD formats can also be output as uncompressed log encoded RAW signals via a standardized 3G SDI interface for connection to external recording systems or across to an on-set video village. Alternatively, the uncompressed 2K / HD formats can be output as log encoded video component sets of RGB 444 @ 12 or 10-bit, or YCrCb @ 10-bit on those same 3G SDI interfaces.

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