EBU - Tech 3335 : Methods of measuring the imaging performance of television cameras for the purposes of characterisation and setting

Alan Roberts, January 2016

SUPPLEMENT 18: Assessment of a Canon EOS C300MkII camera

Tests have been conducted in line with EBU R.118. This document is a report of the results of the tests defined in Tech3335 and is not an endorsement of the product.

This is a report on tests carried out on a Canon C300MkII camera, serial number 963199199242. It is superficially the same as the original C300, but there are several significant changes from the original. The single sensor is super-35mm CMOS Bayer-patterned with 8.85M active photo-sites, probably 26.2x13.8mm, 4096x2160, total 8,847,360 photo-sites, so individual photo-sites must be about 6.4μm square, about 63% more area than in a conventional ⅔" 3-sensor camera. It has a Canon EF lens mount, and there is an optional PL mount.

It records MXF format MPEG4 (AVC H.264), intra-frame or long-GoP, and 4 audio channels 16/24-bit. There is a monocular viewfinder (approximately 1.77Mpixels, not enough for critical-focusing without image magnification) and the hand-grip can be rotated 360 degrees.

The whole sensor is used for 4k recording, slightly cropped for 16:9 formats, pixel-mapped cropping for certain formats (e.g. high-speed HD). Primary recording is onto two CFast: image formats are 4096x2160, 3840x2160, 2048x1080, 1920x1080, with bit rates from 160 to 410Mb/s intra-frame, and 50Mb/s long-GoP. Coding can be YCbCr 4:2:2 10-bit or RGB 10 or 12-bit. Proxy recording is onto SD card: 2048x1080 or 1920x1080, 35 or 24Mb/s long-GoP YCbCr 4:2:0 8-bit. Frame rates are the usual mixture: 59.94p, 59.94i, 50P, 50i, 29.97p, 23.98p, 25p, 24p. Off-speed recording up to 120fps is possible but at reduced resolution above 60fps. Recording times depend on bit-rate, at 410Mb/s a 128GB CFast card can record 40 minutes, at 50Mb/s 335 minutes.

An accessory LCD panel (10.1cm, approximately 1.23Mpixels, not really enough for critic-focusing without image magnification, rotate-able on two axes, and the mount itself can be rotated as well) can be mounted on the top, with or without the carrying handle accessory. It provides XLR audio inputs and controls, plus extra camera controls.

There are neutral filters for exposure control, and manual control of the lens. Sensitivity is good, and noise levels low. On-screen video level monitoring is good but there is no vector-scope option. There is an image magnifier as a focus aid.

Connectivity is good, with SDI (1.5 or 3Gb/s), HDMI, genlock and timecode. Headphone and stereo microphones can both be connected via 3.5 mm jack sockets, independent of the viewfinder.

Power consumption is about 20 watts at 14.4 volts; batteries are effectively internal with options for 2-hour (BP-A30, 3.2Ah) and 4-hour (BP-A60, 6.4Ah) duration plus a 4-pin (non-XLR) connection for external power. The bare camera weighs 1.8kg, which is fairly light for a large-format camera, although this figure can double when the camera is fully equipped with accessories.

There are many assignable buttons: 11 on the main body, 1 on the hand-grip, 10 on the LCD panel, 4 on the remote control.

The camera performed well under test. Tests were made according to EBU Tech.3335, and the results establish that the camera belongs in HD Tier 1 and UHD Tier 2.

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Many of the menu items have little or no effect on image quality. Those that have significant effect are highlighted. The full set of menu items is given for completeness. In boxes with a range of numeric settings, e.g. -99~+99, the values indicate the range, and zero means no alteration to factory setting, not zero effect, and no scales are given in the manuals. For each item, the factory setting is underlined. Menus are nested: items in italics in the listing are headings leading to a further nested menu. The menu structure and contents are very similar to those of the original C300, and in many cases the same settings are appropriate

Camera settings which affect picture quality directly, such as gamma, detail and matrix are held in scene files. These are available via the Custom Picture facility (2nd category in the menus). Other functions such as gain and iris are also controlled by dial/button.

Settings are only starting points, recommendations. They should not be used rigidly, they are starting points for further exploration. However, they do return acceptable image performance.

Measurement results are given in section 3, after the menus. Measurements were made according to the procedures set out in EBU Tech.3335.

This listing of the menus and contents is complete, but this should not be used as an excuse for not reading the manuals. Not all menu items are available in both Camera and Media mode, and some items are missing in the PL version. Any such differences will be dealt with in a later test.

1. Controls and connectors

Main camera body			
Left side from front	ND +	Neutral density filter	
	ND -		
	Magnify (Ass 1)	2:1 image magnification for focussing, steer with Select/Set dial	
	Peaking (Ass 2)	Toggle focus help	
	Zebra (Ass 3)	Toggle Zebra	
	Wfm (Ass 4)	Toggle waveform display	
	Start/Stop	Traditional red button	
	Power	Mode switch	
	ISO/Gain (Ass 5)	Change with Select/Set dial	
	Shutter (Ass 6)	Change with Select/Set dial	
	WB	White balance (or play/pause)	
	Light	Backlight for LCD display	
	Select/Set	Rotate to select, press centre to set	
	Control dial	Rotate for Iris or ISO/Gain	
	WB adjust	WB adjust (or Index/Stop play)	
Back from left	(Ass 8)		
	Func (Ass 9)	Select white balance, ISO/gain, or shutter for control by Select/Set dial	
	Joystick/Set	Navigate menus, press to set option	
	Cancel	Exit menus	
	Menu	Enter menus	
	Slots	Two CFast card slots and battery compartment	
	Slot select	Switch between card slots	
	Video	Multi-pin connections for LCD panel accessory	
	Audio		
	Headphone	3.5mm socket for stereo headphones	

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	Remote	2.5mm socket for RC-V100 or other remote control
	Genlock/Sync	BNC in or out for locking.[1]
	Timecode	BNC in or out
	Mon	BNC monitor, 1.5/3G SDI out, 10-bit RAW/YCbCr
	Rec out	BNC output, 1.5/3G SDI, 10/12-bit RAW/YCbCr/RGB
	HDMI out	1920x1080 or 720x480 (59.94p) or 720x576 (50p)
	DC in	4-pin mini, 16.7V/3A from Canon CA-A10 power supply
Right	Mic	3.5mm socket for stereo mic
	Grip	Handgrip socket and mount
	SD card	Access indicator lamp
Front	SD card	Card slot
	Mic	Built-in mono mic
	Push Auto Iris (Ass 10)	Press and hold for temporary auto iris
	One shot AF (Ass 11)	Press and hold for auto focus, not available in all modes

LCD monitor –operational panel

	Mirror	Flip the image horizontally/vertically
	Fast reverse (Ass 1)	
	Play/pause (Ass 2)	
	Fast play (Ass 3)	Playback controls
	Skip back (Ass 4)	
	Stop (Ass 5)	
	Skip forward (Ass 6)	
Top	Disp (Ass 7)	Cycle through display options, levels of information
	WFM (Ass 8)	Waveform monitoring
	Magn/Index (Ass 9)	Toggle magnification x2, for focus help
	Func (Ass 10)	Assign shutter, gain/ISO, or white balance mode to control dial
	Menu	Enter menus
	Cancel	Exit menus
	Start/Stop	Recording control
	Joystick/Set	Menu navigation, press to set
Under cover	Ch 1, A/M	Auto/Manual level control
	Ch 1, channel	Line/Mic/Mic+48V
	Ch 1, level	Manual level control
	Ch 1, A/M	Auto/Manual level control
	Ch 1, channel	Line/Mic/Mic+48V
	Ch 1, level	Manual level control
Right	Video	Multi-pin connections to the camera
	Audio	
	Input 1	XLR 3-pin
	Input 2	

Hand grip

	Start/Stop	Recording control
	Focus guide	Help with focusing, see the manual for details
	Control dial	Rotate for Iris or ISO/Gain
	Joystick/Set	Menu navigation, press to set

2. Menu contents

Menu settings   Access by menu button, select/set via joystick or control dial. Submenus are indented.

Camera setup

Item	Range	Description
Light Metering	Backlight, Standard, Spotlight	
AE		

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[1] Genlock can accept HD analogue or SD black+burst

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Shift	+2.0 ~ 0 ~ -2.0	In quarter stop increments
Response	High, Normal, Low	
ISO/Gain		
Select	ISO, Gain	
Extended Range	On, Off	Normal is ISO160~12800, extends to 100~102400
ISO Increment	1 stop, ⅓ stop	
Gain Increment	Normal, Fine	3dB or ½dB steps
Iris		
Mode	Automatic, Manual	Depends on the lens
Increment	½ stop, ⅓ stop, Fine	Fine is smaller than ⅓ stop steps
Indicator	F, T	F or T numbers
Zoom-iris Correct	On, Off	Not available on all lenses
Extended ND Range	On, Off	Allows 8 stop and 10 stop ND, but may lose focus
Shutter		
Mode	Speed, Angle, Clear Scan, Slow, Off	Speed=1/sec, Angle=360 to 11¼°, Clear scan=23.98 or 24 to 250Hz, Slow=⅓ or ¼ sec upwards. Depending on system speed
Increment	⅓ stop, ¼ stop	
White Balance		
Shockless WB	On, Off	
AWB Response	High, Normal, Low	
Focus		
Mode	One shot, AF-Boosted MF, Continuous	
Frame Position	Selectable, Center Frame	
Frame Size	Large, Small	
Face Det & Tracking	On, Off	
Face AF	Face priority, Face Only	
AF Speed	-7 ~ 0 ~ +2	
Apply AF Speed Llimit	Always, Only While Recording	
AF Response	+3 ~ 0 ~ -3	
ABB	Cancel, OK	Execute black balance
Color bars		
Activate	On, Off	
Type	SMPTE, EBU, ARIB	Default is EBU in 50Hz countries[2]
Periph Illum Corr	On, Off	Only available for appropriate lenses
Chromatic Aberr Corr	On, Off	

Custom Picture

Item	Range	Description
Preset	Canon Log 2:C.Gamut,. Canon Log 2: BT.2020, Canon Log 2: DCI-P3, Canon Log 2: BT.709, Canon Log, BT.2020, BT.709, Off	Combines gamma and matrix, tailored to the display system[3]
Main settings		See the test report section below
Gamma	Canon Log 2, Canon Log, Wide DR, EOS Standard. Norm 1 Standard, Norm 2 x4.0, Norm 3 BT.709, Norm 4 x5	Canon Log, Log 2 and Wide DR disable some other settings
Color Space	Cinema Gamut, BT.2020 Gamut, DCI-P3 Gamut, BT.709 gamut	
Color Matrix	Neutral, Production Camera, Cinema EOS Original, Video, EOS Standard, Off	
Other Settings		See the test report section below[4]

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[2] SMPTE and ARIB bars are useful for setting up a monitor. Default for 50Hz countries is EBU, but these have no real use any longer, always use either SMPTE or ARIB.

[3] Combines gamma and matrix. Canon Log 2 is wide dynamic range, Log 2 is wider. BT.2020 is UHD 4k), BT.709 is HDTV. C.Gamut is Canon-specific cinema primaries, BT.2020 is UHDTV, DCI-P3 is digital cinema. Use only the correct gamut for your shoot, the others will look wrong.

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Activate	On, <u>Off</u>	Enable other settings
Black		
Master Pedestal	+50 ~ <u>0</u> ~ -50	
Red Pedestal	+50 ~ <u>0</u> ~ -50	
Green Pedestal	+50 ~ <u>0</u> ~ -50	
Blue Pedestal	+50 ~ <u>0</u> ~ -50	
Black Gamma		
Level	+50 ~ <u>0</u> ~ -50	Up/down shift of curve at the point
Range	+50 ~ <u>0</u> ~ -20	Range of effect above the point
Point	+50 ~ <u>0</u> ~ -20	
Low Key Satur		
Activate	On, <u>Off</u>	Saturation in dark areas
Level	+50 ~ <u>0</u> ~ -50	
Knee		
Activate	<u>On,</u> Off	
Slope	+50 ~ <u>0</u> ~ -35	
Point	50 ~ <u>95</u> ~ 109	Break point, percent
Saturation	+10 ~ <u>0</u> ~ -10	Saturation in the compressed part above the point
Sharpness		
Level	+50 ~ <u>0</u> ~ -10	Can take detail out. Nice
H Detail Freq	+8 ~ <u>0</u> ~ -8	Change centre frequency of the hump
Coring Level	+50 ~ <u>0</u> ~ -30	Avoid enhancing noise
Coring D-Ofst	50 ~ <u>0</u>	Set coring level at lowest brightness
Coring D-Curve	8 ~ <u>0</u>	Shape of the transition
HV Detail Bal	+8 ~ <u>0</u> ~ -8	+ to emphasise vertical , - for horizontal
Limit	+50 ~ <u>0</u> ~ -50	Overall limit
Select	15 ~ <u>0</u>	Sharpness for extreme HF
Knee aperture		
Gain	9 ~ <u>0</u>	Sharpness in the knee region
Slope	3 ~ <u>1</u> ~ 0	0=no slope, 1=steep, 3=gradual
Level Depend Level	50 ~ <u>0</u>	Set dark limit level
Level Depend Slope	3 ~ <u>0</u>	
Level Depend Offset	50 ~ <u>0</u>	Sharpness in dark areas, high value=low sharpness
Noise Reduction	12 ~ 1 ~ <u>Off</u>	12=max effect[5]
Skin Detail		Uses zebra to show detected area
Effect Level	High, Middle, Low, <u>Off</u>	
Hue	+16 ~ <u>0</u> ~ -16	Skin hue to detect
Chroma	+16 ~ <u>0</u> ~ -16	Skin saturation to detect
Area	31 ~ <u>16</u> ~ 0	Extent of skin range
Y level	31 ~ <u>16</u> ~ 0	Luma level to detect
Selective NR		Uses zebra to show detected area
Effect Level	High, Middle, Low, <u>Off</u>	Hue to affect
Hue	+16 ~ <u>0</u> ~ -16	Saturation to affect
Chroma	+16 ~ <u>0</u> ~ -16	Chroma to affect
Area	31 ~ <u>16</u> ~ 0	Range to affect
Y Level	31 ~ <u>16</u> ~ 0	Luma level to affect
Color Matrix Tuning		
Gain	+50 ~ <u>0</u> ~ -50	Colour level
Phase	+18 ~ <u>0</u> ~ -18	Colour phase or hue
R-G	+50 ~ <u>0</u> ~ -50	
R-B	+50 ~ <u>0</u> ~ -50	
G-R	+50 ~ <u>0</u> ~ -50	
G-B	+50 ~ <u>0</u> ~ -50	
B-R	+50 ~ <u>0</u> ~ -50	
B-G	+50 ~ <u>0</u> ~ -50	

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[4] Generally, these settings can be left alone, since the Presets are very good. Dive into this section only if you really know what you're doing.

[5] Noise reduction also reduces resolution and aliasing. Setting to between 3 and 5 in reducing both noise and aliasing..

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White Balance		Tint the whole tonal range
R Gain	+50 ~ <u>0</u> ~ -50	
B Gain	+50 ~ <u>0</u> ~ -50	
Color Correction		Uses zebra to show affected area
Select area	Area A, Area B, Area A&B, <u>Off</u>	Two colours can be controlled
Area A Setting Phase	31 ~ <u>0</u>	
Area A Setting Chroma	31 ~ <u>16</u> ~ 0	Colour detection
Area A Setting Area	31 ~ <u>16</u> ~ 0	
Area A Setting Y Level	31 ~ <u>16</u> ~ 0	
Area A Revision Level	50 ~ <u>0</u> ~ -50	Colour modification
Area A Revision Phase	18 ~ <u>0</u> ~ -18	
Area A Setting Phase	31 ~ <u>0</u>	Colour detection
Area A Setting Chroma	31 ~ <u>16</u> ~ 0	
Area A Setting Area	31 ~ <u>16</u> ~ 0	
Area A Setting Y Level	31 ~ <u>16</u> ~ 0	
Area A Revision Level	50 ~ <u>0</u> ~ -50	Colour modification
Area A Revision Phase	18 ~ <u>0</u> ~ -18	
Other Functions		
Setup Level	50 ~ <u>0</u> ~ -50	Adds to Master pedestal
Over 100%	<u>Through</u>, Clip, Press	White clipping, press compresses

Audio Setup

Item	Range	Description
Audio Input		
Audio Bit Depth	<u>24bit</u>, 16bit	
Ch2 Input	<u>Input 2</u>, Input 1	
Input 1 Mic Trimming	+12, +6, <u>0</u>, -6, -12dB	
Input 1 Mic Att	On, <u>Off</u>	
Input 2 Mic Trimming	+12, +6, <u>0</u>, -6, -12dB	
Input 2 Mic Att	On, <u>Off</u>	
Input 1&2 ALC Link	Linked, <u>Separated</u>	
Input 1&2 Limiter	On, <u>Off</u>	
Mic Mode	<u>Automatic</u>, Manual	
Mic Level	99 ~ <u>50</u> ~ 0	
Mic Att	On, <u>Off</u>	
Mic Low Cut	On, <u>Off</u>	
1kHz Tone	-12dB, -18dB, -20dB, <u>Off</u>	
Audio Output		
Headphone Volume	Off, 1 ~ <u>8</u> ~ 15	
Monitor Channels	<u>Ch1/Ch2</u>, Ch1,Ch1, Ch2,Ch2, Ch1+2/Ch1+2, Ch3/Ch4, Ch3/Ch3, Ch4/Ch4, Ch3+4/Ch3+4, Ch1+3/Ch2+4	
HDMI Out Channels	<u>Ch1/Ch2</u>, Ch3/Ch4	
4k RAW Channels	<u>Ch1/Ch2</u>, Ch3/Ch4	

Recording/Media Setup

Item		Range	Description
Initialize Media		CFast A, CFast B, SD Card	Cancel, Ok for CFast: Complete, Quick for SD
System Frequency		<u>59.94</u>, <u>50</u>, 24	Default depends on the country the camera is sold in
Rec Out 4k RAW Mode		4k RAW, <u>2k</u>, Off	
4k RAW Color Space		BT.2020 Gamut, <u>Cinema Gamut</u>	[6]
Recording Mode		<u>Normal</u>, Slow&Fast, Slow&Fast Crop, Pre-rec, Frame, Interval	Slow&Fast=1~60 or 50, Slow&Fast crop=1~120 or 100 cropped. Pre-rec is a cache,
Frame Rate	59.94	59.94i, 59.94p, <u>29.97p</u>, 23.98p	
	50	50i, 50p, <u>25p</u>	
Resolution/Color Sampling		4096x2160 YCC422 10bit, <u>3840x2160 YCC422 10bit</u>, 2048x1080 YCC422 10bit, 1920x1080	

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[6] Cinema gamut needs ACES processing software, BT.2020 is correct for UHDTV

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		YCC422 10bit, 2048x2160 RGB444 12bit, 1920x1080 RGB444 12bit, 2048x1080 RGB444 10bit, 1920x1080 RGB444 10bit	
Bit Rate		310 I-Frame, 160 Intra-Frame, 50 Long-Gop	Range depends on frame rate, this is for 1080 YCbCr422 10bit
Special Recording Settings			
S&F Frame	59.94/24	1 ~ <u>30</u> ~ 60	1 ~ 30 for 4k, 1 ~ 120 for crop mode
Rate	50	1 ~ <u>25</u> ~ 50	1 ~ 25 for 4k, 1 ~ 100 for crop mode
Frame Recording			
Recorded Frames		<u>1</u>, 3, 6, 9	
Interval Recording			
Interval		<u>1 sec</u>, 2, 3, 5, 10, 15, 30, 1min, 2, 3, 4, 10min	
Recorded Frames		<u>1</u>, 3, 6, 9	
XF-AVC Proxy Recording			
Activate		On, <u>Off</u>	
Apply LUT		BT.709, BT.2020, DCI, <u>Off</u>	
Relay/Double Slot Rec			
Relay Recording		On, <u>Off</u>	
Double Slot Recording		On, <u>Off</u>	
Metadata			
Camera Index		<u>A</u> ~ Z, Set	
Reel Number		<u>001</u> ~ 999, Set, Reset	
Clip Number		<u>001</u> ~ 999, Set, Reset	
User Defined		<u>Canon</u>, Set	5 characters using A to Z and 0 to 9
Scene		Set, Reset	16 characters using A to Z, 0 to 9 etc
Take		Set, Reset	16 characters using A to Z, 0 to 9 etc
Setting		Remote, <u>SD Card</u>	
User Memo		<u>Off</u>, List	Lists all user memo files on SD card
Country Code		Set	ISO-3166-1. 4 characters using A to Z, 0 to 9 etc
Organization		Set	SMPTE code. 4 characters using A to Z, 0 to 9 etc
User Code		Set	4 characters using A to Z, 0 to 9 etc
Add CP File		<u>On</u>, Off	Embeds Custom data in the clip
Rec Command		<u>On</u>, Off	Link control to external recorder
HDMI Time Code		On, <u>Off</u>	Add time code to HDMI
Clips			
Copy All Clips		Cancel, OK	
Copy OK Clips		Cancel, OK	
Delete All Clips		Cancel, OK	
Photo Numbering		Reset, <u>Continuous</u>	
Delete All OK Mmarks		Cancel, OK	
Delete All hotos		Cancel, OK	

Picture/Terminals Setup

Item	Range	Description
Select Monitoring Devices	Mon+HDMI+LCD/VF, Mon+HDMI+VF, <u>LCD+VF</u>	
Mon Terminal		
Output	4k RAW Priority, 2048x1080/1920x1080, <u>1920x1080</u>, Off	
OSD Output (2k)	<u>On</u>, Off	
3G-SDI Mapping	Level A, <u>Level B</u>	SMPTE ST 425-1
Genlock/Sync Out Term		
Select	HD Sync Out, <u>Genlock In</u>	
Genlock Adjustment	+1023 ~ <u>000</u> ~ -1023, Set	
Sync Scan Mode	<u>P</u>, PsF	
Timecode		
Mode	<u>Preset</u>, Regen	
Run	<u>Rec Run</u>, Free Run	
DF/NDF	DF, <u>NDF</u>	Default depends on system frequency
Setting	00:00:00:00 ~ 23:59:24, Set	

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	Reset	
TC In/Out	<u>In</u>, Out	
User Bit		
Recording Mode	<u>Internal</u>, External	
Type	<u>Setting</u>, Time, Date	
LCD Setup		
Brightness	+99 ~ <u>0</u> ~ -99	
Contrast	+99 ~ <u>0</u> ~ -99	
Color	+20 ~ <u>0</u> ~ -20	
Sharpness	4 ~ <u>2</u> ~ 1	
Backlight	<u>Normal</u>, +1, +2	
Viewfinder Setup		
Brightness	+99 ~ <u>0</u> ~ -99	
Contrast	+99 ~ <u>0</u> ~ -99	
Color	+20 ~ <u>0</u> ~ -20	
Sharpness	4 ~ <u>2</u> ~ 1	
Luminance	<u>Normal</u>, High	
Eye sensor	<u>On</u>, Off	
Panel Luminance	5 ~ <u>3</u> ~ 1	
Disp button Levels		
All Displays	<u>On</u>, Off	
Surrounding Icons	<u>On</u>, Off	
Markers	<u>On</u>, Off	
No dDsplays	<u>On</u>, Off	
Custom Display 1		
Light Metering	<u>On</u>, Off	
Custom Picture	<u>On</u>, Off	
Focal Length	<u>On</u>, Off	
ND Filter	<u>On</u>, Off	
Focus Mode	<u>On</u>, Off	
Key Lock	<u>On</u>, Off	
White Balance	<u>On</u>, Off	
Exposure	<u>On</u>, Off	
Iris	<u>On</u>, Off	
ISO/Gain	<u>On</u>, Off	
Shutter	<u>On</u>, Off	
Peaking	<u>On</u>, Off	
Magnification	<u>On</u>, Off	
LUT	<u>On</u>, Off	
Lens	<u>On</u>, Off	
Custom Display 2		
Remaining Battery	Only Warnings, <u>Normal</u>, Off	
Remaining Rec Time	Only Warnings, <u>Normal</u>, Off	
Recording Mode	<u>On</u>, Off	
Genlock	<u>On</u>, Off	
Time Code	<u>On</u>, Off	
Reel/Clip Number	<u>On</u>, Off	
Interval Counter	<u>On</u>, Off	
Remaining Photos	Only Warnings, <u>Normal</u>, Off	
Temperature/Fan	<u>On</u>, Off	
Resolution/Color Sampling	<u>On</u>, Off	
Frame Rate	<u>On</u>, Off	
OSD Recording	<u>On</u>, Off	
Output Terminals Status	<u>On</u>, Off	
OSD Output	<u>On</u>, Off	
Rec Command	<u>On</u>, Off	
User Memo	<u>On</u>, Off	
User Bit	<u>On</u>, Off	

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Item	Range	Description
Monitor Channels	On, Off	
Audio Level	On, Off	
Network Functions	On, Off	
GPS	On, Off	
Date/Time	Date/Time, Time, Date, Off	

Assistance Functions

Item	Range	Description
Focus Guide	On, Off	
Peaking		
Activate	On, Off	
Display on LCD	On, Off	
Display on VF	On, Off	
Output to Mon&HDMI	On, Off	
Select	Peaking 1, Peaking 2	
Peaking 1		
Color	White, Red, Yellow, Blue	
Gain	15~ 8 ~ 1, Off	
Frequency	4 ~ 2, 1	
Peaking 2		
Color	White, Red, Yellow, Blue	
Gain	15 ~ 1, Off	
Frequency	4 ~ 1	
Focus Assistance B&W	On, Off	
Zebra		
Activate	On, Off	
Display on LCD	On, Off	
Display on VF	On, Off	
Output to Mon&HDMI	On, Off	
Select	Zebra 1, Zebra 2, Zebra 1&2	
Zebra 1 Level	70±5, 75±5, 80±5, 85±5, 90±5, 95±5%	10% zones
Zebra 2 Level	70, 75, 80, 85, 90, 95, 100%	Everything over the threshold
Magnification		
Display on LCD	On, Off	
Display on VF	On, Off	
Display on Mon&HDMI	On, Off	
Focus Assistance B&W	On, Off	
Markers		
Activate	On, Off	
Center	Black, Gray, White, Off	
Horizontal	Black, Gray, White, Off	
Grid	Black, Gray, White, Off	
Aspect Marker	Black, Gray, White, Off	
Aspect Ratio	4:3, 13:9, 14:9, 16:9, 1.375:1, 1.66:1, 1.75:1, 1.85:1, 1.9:1, 2.35:1, 2.39:1, Custom	
Custom Aspect Ratio	1.00~9.99:1	
Safe Area	Black, Gray, White, Off	
Basis for Safe Area	Whole Picture, Selected Aspect Marker	
Percentage of Safe Area	80, 90, 92.5, 95%	
LUT		
Activate	On, Off	
Mon & HDMI (2k)	BT.709, BT.2020, DCI, ACESproxy10, Off	
Rec Out (2k)		
LCD & VF	BT.709, Off	
B&W Image		
Activate	On, Off	
Display on LCD	On, Off	
Display on VF	On, Off	

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Output to Mon & HDMI	On, Off	

WFM

Activate	On, Off	
Output	LCD, VF, Mon & HDMI, All	

Waveform Monitor

Type	Line, Line+Spot, Select Line, Field, RGB, YPbPr	
Gain	1x, 2x	
Y Position	0, 15, 30, 45, 50%	

Select Line	1080	1079 ~ 540 ~ 0	1-line steps
	2160	2158 ~ 1080 ~ 0	2-line steps

System Setup

Item	Range	Description
Reset		
All Settings	Cancel, OK	
Camera Settings	Cancel, OK	
Assignable Buttons	Cancel, OK	
Transfer Menu/CP		
Save	To Camera, To SD	
Load	From Camera, From SD	
Time Zone		List of all time zones, default -5 New York or +1 Central Europe
Set Clock		
Date/Time		
Date Format	YMD, YMD/24H, MDY, MDY/24H, DMY, DMY/24H	MDY for 60Hz countries, DMY for 50Hz countries
Language		List of languages[7]
Remote Term	RC-V100, Standard	
Assignable Buttons		
Camera (1~11)	None, One Shot AF, AF Lock, Focus Guide, Face AF, Face Det & Tracking, Tracking, Push Auto Iris, Iris Mode, Iris +, Iris -, ND +, ND -, AE Shift +, AE Shift -, Backlight, Spotlight, Func, Shutter, ISO.Gain, White Balance, Peaking, Zebra, WFM, Magnification, Color Bars, Markers, LCD Setup, Viewfinder Setup, LUT, OSD Output, Display, Add Shot Mark 1, Add Shot Mark 2, Add OK Mark, Add Tick Mark, Time Code, Time Code Hold, Headphones +, Headphones -, Monitor Channels, Audio Level, Photo, Review Recording, S&F Frame Rate, Status, Custom Picture, My Menu, Initialize Media, Index, Star User Setting	Defaults: 1=Magnification, 2=Peaking, 3=Zebra, 4=WFM, 5=ISO/Gain, 6=Shutter, 7=S&F Frame Rate, 8=None, 9=Func, 10=Push Auto Iris, 11=One-Shot AF
Grip (1)		Default: 1=Focus Guide
Monitor (1~10)		Defaults: 1~6=None, 7=Display, 8=WFM, 9=Magnification, 10=Func
Remote Controller (1~4)		Defaults: 1=Magnification, 2=Peaking, 3=Zebra, 4=WFM
Tally Lamp	On, Off	
Media Access LED	On, Off	
Fan		
Mode	Automatic, Always On	
Fan Speed (STBY)	Maximum, High, Middle, Low	
Fan Speed (REC)	High, Middle, Low	
Fan Speed (Always)	High, Middle, Low	
Fan Speed	High, Middle, Low	This is for playback mode
Review Recording	Entire Clip, Last 2 sec	
Custom Function		
Camera Control Dial	Iris, ISO/Gain, Off	
Grip Control Dial	Iris, ISO/Gain, Off	
Camera Control Dial Dir	Reverse, Normal	
Grip Control Dial Dir	Reverse, Normal	
Select Dial Dir	Reverse, Normal	

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[7] Beware of changing language, you might not be able to read the menus to find the way back.

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Retract Lens	On, Off	Retracts lens on power off, EF 40 STM and EF-S 24 STM
3D Rec Mode	On, Off	
Scan Reverse Mode	Both, Vertical, Horizontal, Off	
Displayed Units	Meters, Feet	
OSD Recording (CFast)	Time Code/Date/Time, Date/Time, Time Code, Time, Date, Off	
Start/Stop Button		
Camera	Disable, Enable	
Grip	Disable, Enable	
Monitor	Disable, Enable	
Key Lock	All Buttons, Except for Start/Stop	Which buttons get locked by the power switch when recording
Reset Hour Meter	Cancel, OK	
Network Settings		
Browser Remote		Consult 'WFT-E6: Guide for EOS C300MkII Users' pdf
Activate	On, Off	
Camera ID		
Port No		
Users Settings		
Media Server		
Connection Settings		
GPS		
Activate	On, Off	
Auto Time Setting	On, Off	
Certification Logos		Information only
Firmware		
Camera	1.0.1.1.00	Information only
Lens	1.0.3	Information only

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3. Measurements

All measurements were made on frames captured onto a CFast card. Live viewing was done on a 24" Canon 4k studio monitor (DP-V2410). Clips were ingested into Edius 8.10 and images for this document were extracted as BMP files. Gain was applied within Edius for some images. In all cases, the project resolution was set to match the clip resolution thus avoiding any scaling.

The lens was a Canon EF 24~70mm F4 L IS USM short zoom, serial number 0100009625. I shall use the EBU system of designating scanning standards (e.g. 25i is what is commonly called 50i).

3.1. Colour performance

A standard Colorchecker chart was exposed, using tungsten illumination. The camera was allowed to auto-white balance. The camera has several shooting modes which have great effect on the colour performance; it would be wrong to compare these without including the display system that each is intended for. Nevertheless, it is useful to compare them because it illustrates the need for acceptable bit-depth.

Fig 1 shows the results for five of the possible conditions, all at the same exposure.

Figure 1: Colorchecker
a: Preset off   b: Preset BT.709   c: Preset Canon Log   d: Preset Canon   e: Preset Canon
   Normal 3 (BT.709)   Log 2 : BT.709   Log 2 : C.Gamut

Fig.1:a shows a normal camera setting, no presets, just the default values for Normal 3 Gamma, Color Space and Color Matrix. For this setting 8-bit coding would be quite adequate since there would not normally be significant post-processing. Fig.1:b~e show the preset conditions. Preset BT.709 is desaturated because the gamma curve is somewhat flattened, the Canon Log curves increase this flattening, but the C.Gamut (Cinema Gamut) version is very flat because it is aimed at wide gamut cinema primaries. Similarly the DCI-P3 and BT.2020 versions are aimed at specific sets of primaries and so cannot be corrected to BT.709 display using conventional post-processing. Use these settings with care, but the presets deliver perfectly acceptable results for their intended usage, bearing in mind that DCI-P3 and C.Gamut probably need 12-bit recording to avoid visible colour-contouring, and BT.2020 must use at least 10-bit.

Colour performance tests showed no problems.

3.2. Gamma curves (opto-electronic transfer characteristic) and Dynamic Range

The Colorchecker chart was exposed with tungsten illumination, using three of the presets. Multiple exposures, using neutral density filters, provided many exposure levels from which it is possible to extract the curves from the grey scale patches.

Fig. 2 shows the curves for BT.709, Canon Log and Canon Log 2. The plot is of video signal level versus actual exposure, in stops relative to the exposure level needed to cause peak white from the chart's white patch, when using the BT.709 curve. The lines are not quite smooth because there is no guarantee that the neutral density filters

Figure 2: Gamma curves

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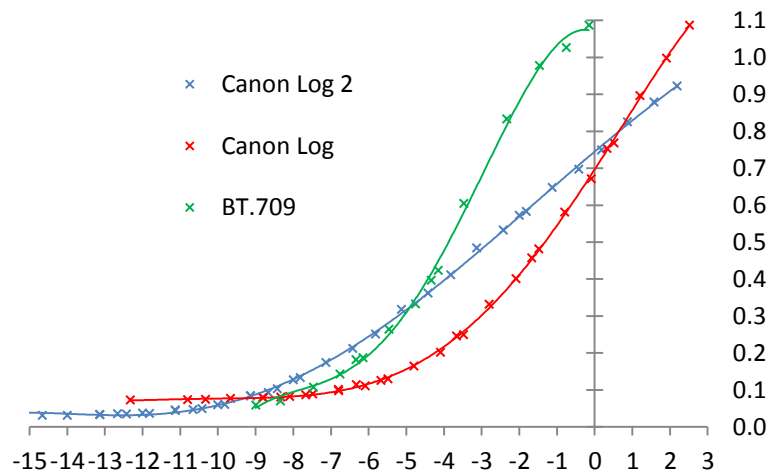
have exactly the specified density, and measurement of small patches inevitably results in some uncertainty.

Clearly, there is a knee in the BT.709 curve (in the version used in Preset BT.709), and the overall dynamic range is 11.5 stops (7 stops plus the 78.76:1 contrast on the card which is equivalent to 4.846 stops), as expected. The Canon Log curve captures a range of about 13.5 stops (9 stops latitude plus 4.8). Canon Log 2 captures about 15 stops (about 11 stops latitude plus 4.8). These conclusions were confirmed by visual inspection of the grabbed images. The lower slope of the Canon Log 2 curve points to the conclusion that use of this curve will require at least 10-bits, and the 12-bit 444 mode is required for best colour performance with this curve. The other curves are suitable for 10-bit recording.
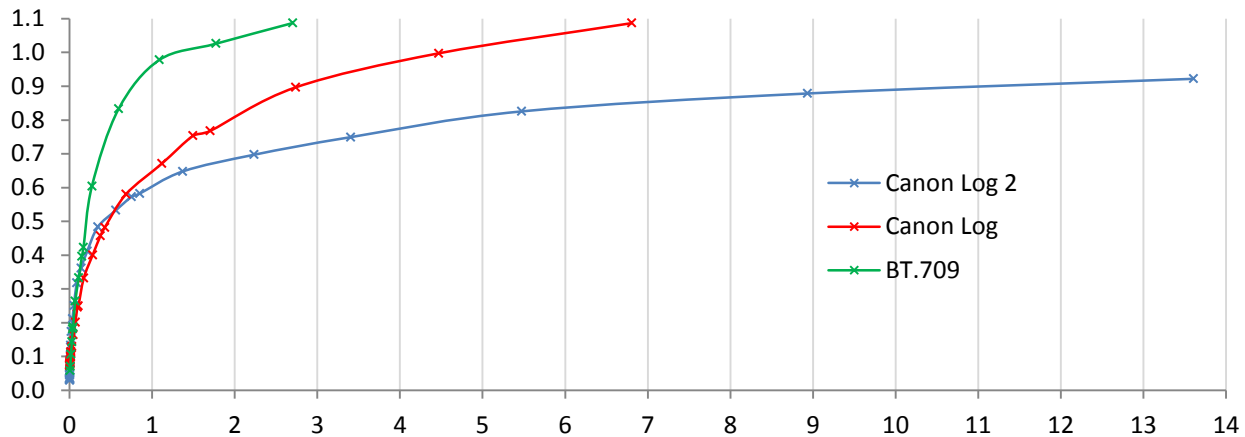
Figure 3: Gamma curves, linear

Fig. 3 shows the same data replotted with linear horizontal axis, exposure, rescaled such that the BT.709 curve reaches nearly to 100% before being bent by a built-in knee which can capture about 280% exposure.

Fig. 4 shows measurements of Canon Log 2 using the 12-bit recording format (RGB 444). The file was ingested into Edius using a 10-bit YCrCb project, I do not know what conversion process is used, but simply exported BMP bitmap files as usual, without any other processing. Adding 6dB and 12dB gain confirmed that the dynamic range is indeed about 15 stops.
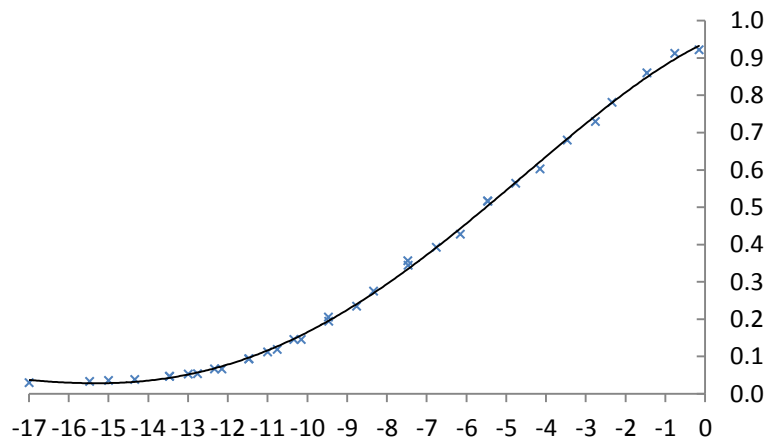
Figure 4: Canon Log 2, 12-bit recording

3.3. Resolution and aliasing

3.3.1. Resolution for '4K' (UHD-1)

Tests were made at F/8. The usual zone plate test chart was framed to fill exactly half the width and height of the image. Thus the calibrated dimensions should all be doubled. Recording was 3840x2160 YCC 422 10bit at 410Mb/s I-frame, with standard BT.709 settings.

Fig. 5 shows one quadrant of the luma pattern which now reaches the 3840x2160 limits of UHD-1.

The modulation is extinguished above 3300 horizontally, and 1750 vertically. However, aliasing
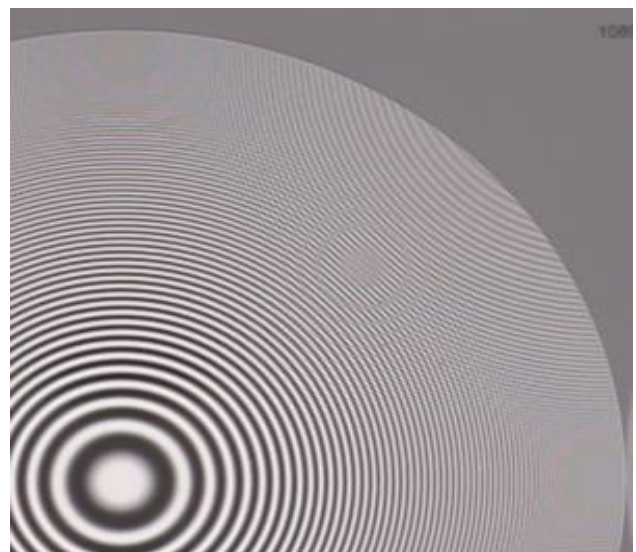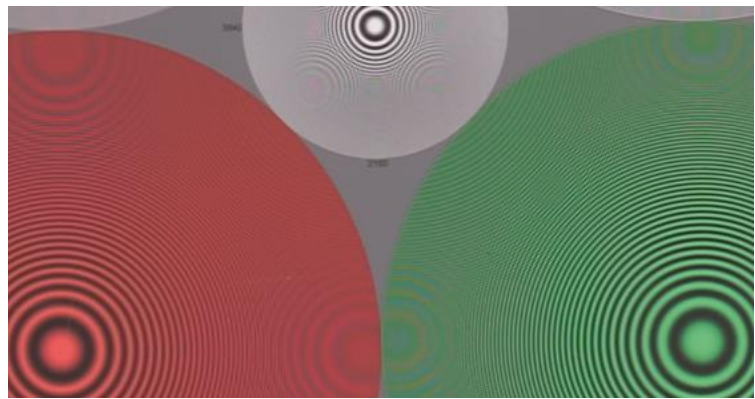

Figure 5: Resolution 3840x2160, luma

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obtrudes in the diagonal directions within both these limits, which is inevitable with a Bayer-patterned sensor.

Fig. 6 shows quadrants of red and green. The red pattern resolution (and that of blue) is lower than the green, which is inevitable with a Bayer-patterned sensor, but the level of aliasing is not particularly high. Fig. 6 also shows half of a smaller pattern which extends to 7680x4320 and reveals that the optical low-pass filter is not wholly removing spatial content above 3840x2160. Nevertheless, the performance is quite good.

Figure 6: Resolution 3840x2160, red and green

3.3.2. Resolution for HDTV (1920x1080)

Exposures were made at F/6.3. The zone plate chart was framed to exactly fill the image. The image for 1920x1080 HD comes from a 3840x2160 part of the sensor, thus there seems to be no need to decode the Bayer pattern since each of the red and blue sub-patterns are 1920x1080, and the green sub-pattern has two, spatially offset, patterns of 1920x1080. However, this would cause serious aliasing since the optical low-pass filter must be tailored to the 4k performance of the camera. Therefore we should expect to see the effects of down-scaling in the HD performance, i.e. some aliasing.

Fig. 7 shows luma quadrants reaching 1920x1080 and 3840x2160 (the smaller pattern). Resolution reaches the limits for HDTV, and the level of aliases within the limits quite low. However, the smaller pattern shows clearly that the down-scaling is passing frequencies beyond HDTV, particularly in the horizontal direction.
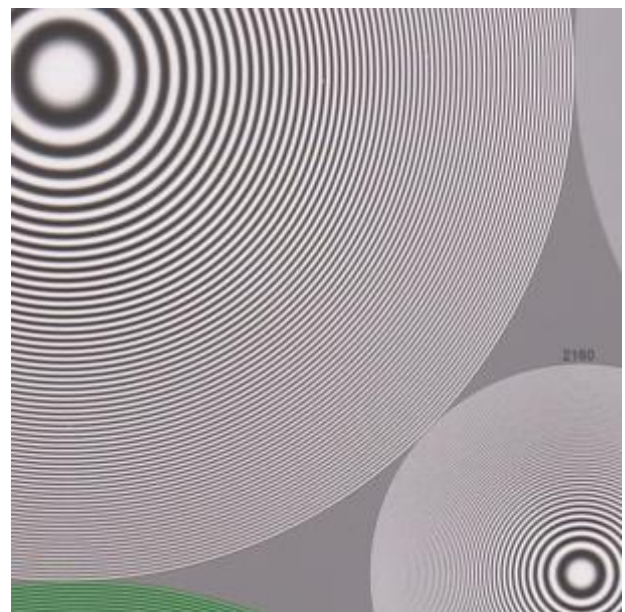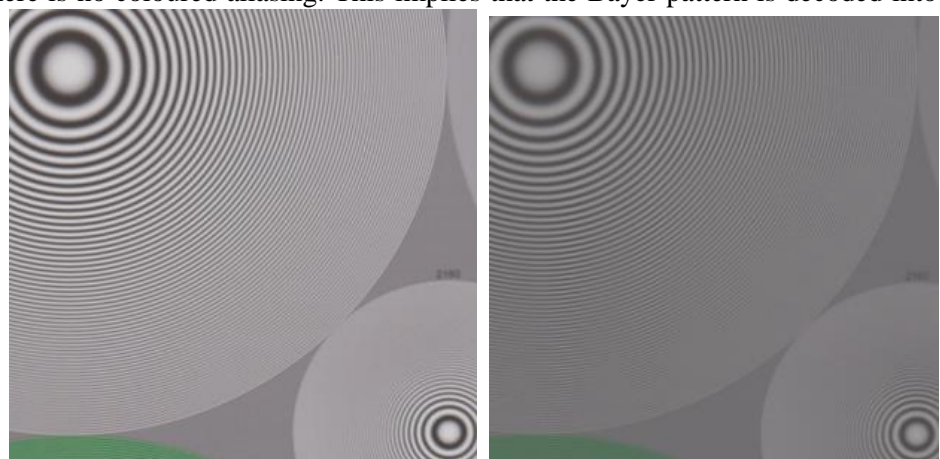

Figure 7: Resolution 1920x1080, luma

This exposure used the default gamma and other settings rather than any of the presets, and YCbCr422 10-bit recording.

The aliasing is all in luma, there is no coloured aliasing. This implies that the Bayer pattern is decoded into separate red, green and blue channels, each up-scaled to 3840x2160, before down-scaling to 1920x1080.

In theory, the video settings can affect the aliasing levels, so Fig. 8 shows the same quadrants recorded using Preset BT.709 and Preset Canon Log 2 : BT.709. These are both at the same exposure as used in Fig. 7.

It is clear that the Presets

Figure 8: Resolution 1920x1080, luma
a: Preset BT.709

b: Preset Canon Log 2 : BT.709

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reduce the level of aliasing quite dramatically, but the resolution is also reduced. This is inevitable, since both the detail-enhancement levels and the contrast range are quite different. However, it demonstrates that the Presets are to be preferred over tinkering with the other menu controls.

Therefore, I have not investigated these other controls.

3.4. Noise

3.4.1. Noise levels

The camera was exposed to a 6-step grey scale, tungsten illuminated. Multiple exposures were taken to give 36 measurements, exploring the dynamic range at ISO800 (12dB Gain). Shooting was 1920x1080 HD using the default BT.709 settings (not the Preset). Fig. 9 shows the result, noise levels plotted vertically versus signal level. The solid line is a trend line through (or nearly through) the luma points.
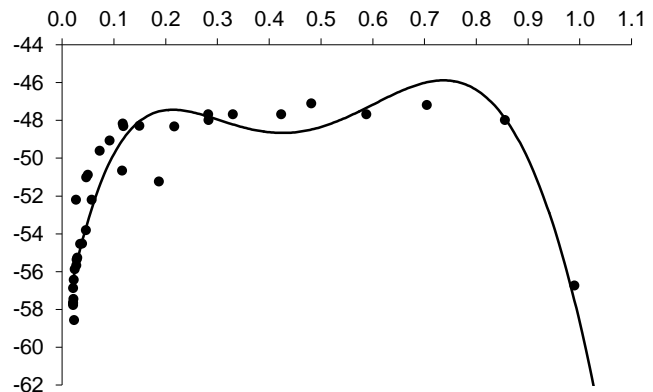
Figure 9: Noise profile, 1920x1080, BT.709, ISO800

Conventionally, the noise level would be expected to rise near black since the differential gain applied by gamma correction affects the noise level, but here it drops dramatically. There are several possible reasons, but it is hardly worth exploring these since the user has no control over the noise profile. The noise level at 50% video is about -48dB which is the qualifying level for EBU R.118 HD Tier 1. However, since the noise level falls from this level towards black, the pictures look much less noisy than these figures imply.
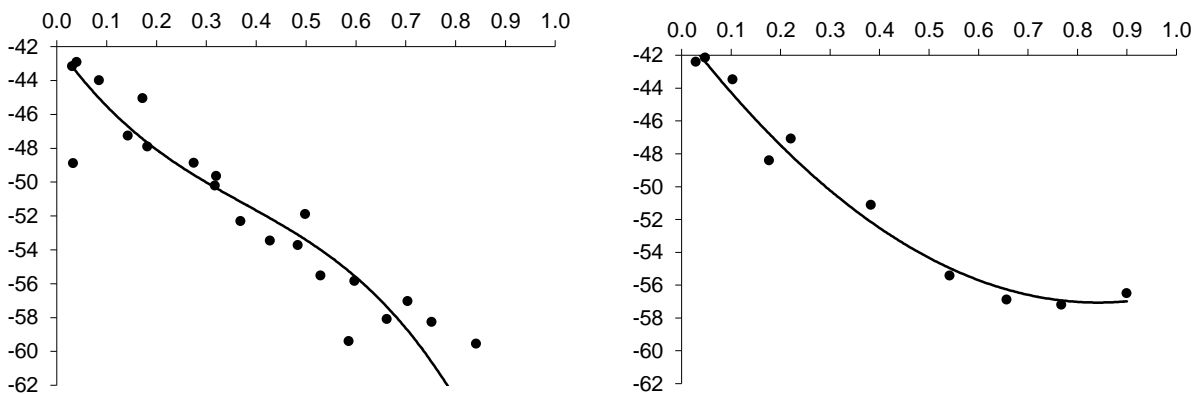
Figure 10: Noise profile, 1920x1080, ISO800, Canon Log 2
a: 1920x1080   **b: 3840x2160**

Fig. 10 shows the same measurements for Canon Log 2, in both 1920x1080 and 3840x2160 modes. Here, the profile shape is much more traditional, rising towards black. I have no explanation for this. However, at mid-grey, the assessment level for camera tiering, the noise level is nicely below -50dB, although it is a little noisier in 3840x2160 mode.

Next, the camera was exposed to a pair of Kodak Gray cards, showing 90% white and 18% grey sides together. Exposure was adjusted to achieve 50% luma level from the grey card over the full range of ISO settings. Exposure was controlled using the neutral density filters shutter and iris. Fig. 11 shows the
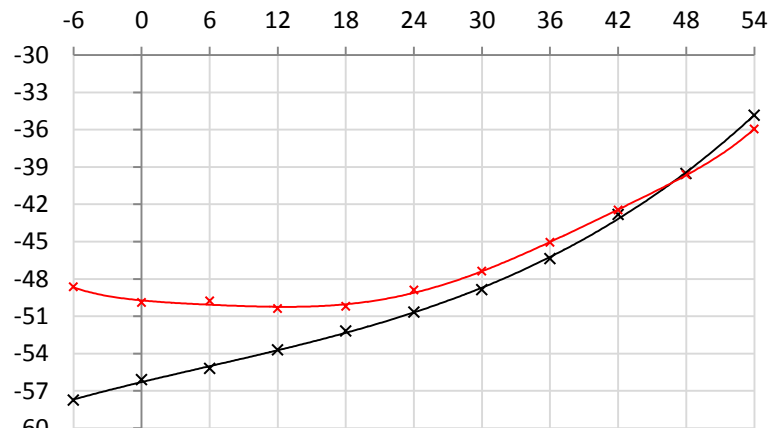
Figure 11: Noise level versus Gain

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result for 1080 in black, 2160 in red.

Noise levels are plotted versus the ISO setting expressed as Gain in dB, with 0 being ISO 200. The 'normal' curve for this test would be a linear slope, rising by 3dB in noise level with each 6dB in gain. The deviation from this ideal indicates that there is some signal processing, probably noise reduction, going on which is one of the possible reasons for the unconventional profile shapes in Figs. 9 and 10. Nevertheless, the noise level of -48dB is held up to about 32dB gain, or ISO 6400.

3.4.2. Noise reduction

To test this facility, 1920x1080 exposures were made at all the ISO settings, keeping the video level from a Kodak Gray (18%) at or very near 10%. Exposures were made with noise reduction off, and then with it set to maximum level - 12.

Fig. 12 shows the results, plotted as noise level improvement in dB versus unimproved noise level. Typically, there is 5dB improvement, but only when the noise levels are relatively high, such as when using higher ISO or gain values (in this case higher than ISO800, +12dB gain), which is exactly when it is needed.
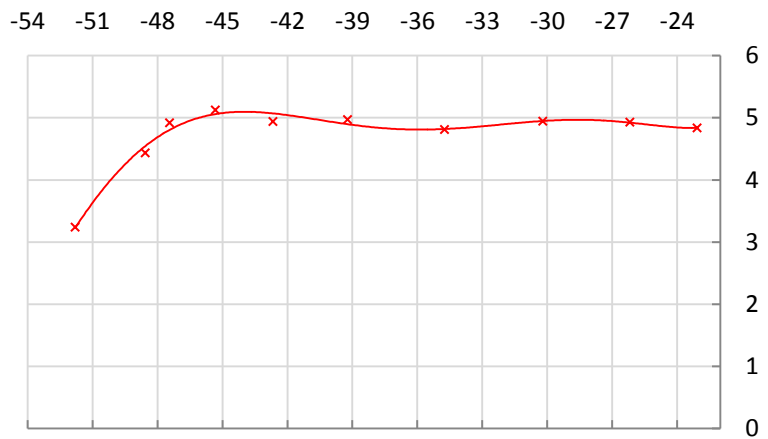

Figure 12: Noise reduction

However, noise reduction always comes at a price, usually a loss of resolution due to the action of the spatial filtering used in noise reduction. Fig. 13 shows zone plate quadrants at ISO6400 (30dB gain), with noise reduction off and on (maximum level, 12). The loss of resolution might be acceptable, but is clearly visible nevertheless. The effect is more marked at higher speed.
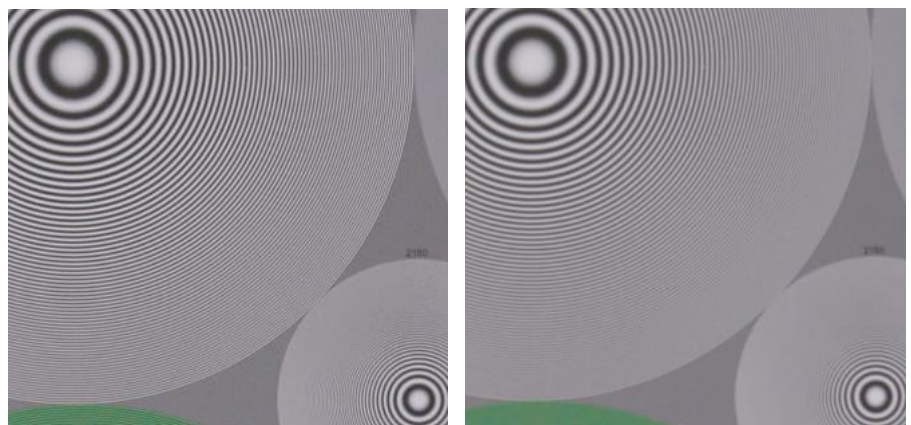
Fig 14 shows the same conditions at ISO25600 (42dB gain). Here, the loss of resolution is much more dramatic, although the resolution without noise reduction has also dropped a little.
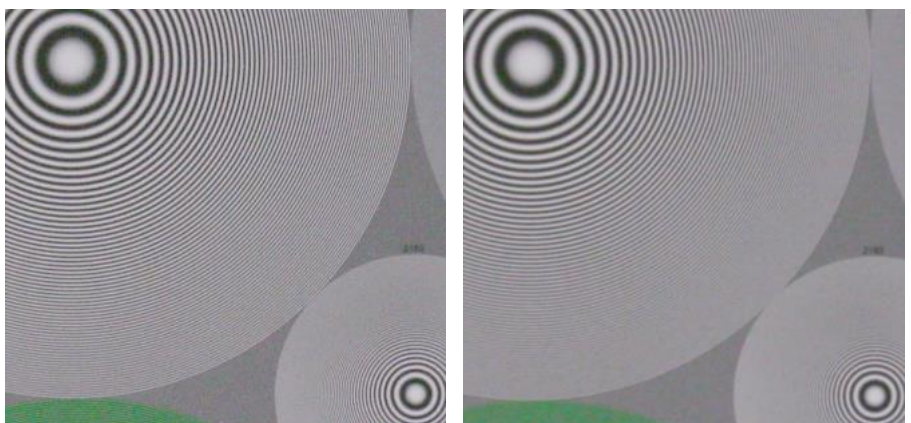
Fig. 15 shows what I consider to be an acceptable compromise between the level of noise reduction and resolution loss. Setting noise reduction to 6 ought to deliver 2.5dB noise reduction, with a slight drop in perceived resolution.

Figure 13: Zone plate, 1920x1080, ISO6400 (30dB)
a: Noise reduction off   **b: Noise reduction maximum (12)**

Figure 14: Zone plate, 1920x1080, ISO 25600 (42dB)
a: Noise reduction off   **b: Noise reduction maximum (12)**

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However, this should be compared with the performance at ISO160, Fig. 1. There is a clear drop in resolution, but the result is still acceptable, perhaps more so because the level of aliasing is reduced. So, this could point to the use of mild noise reduction as a means to lower the level of aliasing, between say 3 and 5 appears to be a good compromise.

3.5. Sensitivity

In a television camera, sensitivity is normally defined as the lens aperture required to produce 100% peak white from a white card with a reflectance of 90%, lit by 2000 lux. This usually assumes a standard setup condition of either no gamma-correction or a curve which follows the normal equation, i.e. without a knee, and with interlaced scanning using 1/50 exposure interval. This camera will never be used in such a condition, so an alternative approach is needed.

Figure 15: Zone plate, 1920x1080, ISO 25600 (42dB), noise reduction = 6

The most sensible approach is to use the Kodak Gray cards again. The grey side has a reflectance which is 20% relative to the white side. From this input level, the BBC 0.4 gamma law should produce 50% video, and the BT.709 curve about 42% video level. Minor differences between standard gamma curves have little effect, so this is a good way to assess the sensitivity.

The card was lit at 2000 lux, and aperture adjusted to get 50% video level using 'Normal 4 x5' gamma curve and 1/50 shutter (e.g. using 50p mode) and ISO800. The exposure was F/11, and the white card produced 100% video level, confirm that this mode is actually the BBC 0.4 law. With 'Normal 3 BT.709' gamma curve, the grey card produced about 42% and the white was unchanged, again confirming that this is the BT.709 curve. 'Preset BT.709' again produced 42% for the grey but only 80% for the white card, confirming that there is a permanent knee in this curve.

For the grey card to produce 50% video level, the exposure in 'Preset BT.709' was between F/10 and F/11, while for 'Preset Canon Log' it was F/10 and for 'Preset Canon Log 2' F/9. Thus the sensitivity lies between F/11 and F/9, depending on the gamma curve chosen. The same results apply to both 1080 and 2160 shooting.

3.6. Infra-red response

No camera should respond to infra-red - if we can't see it, neither should a camera. The simplest test for this is to point a conventional remote-control into the lens and press a button. If the camera shows the LED, it is seeing infra-red. Although there is a very slight response, it is of no significance in practice.

3.7. Motion portrayal

The sensor is CMOS, which can be read either by scanning or by instantaneous transfer into a readout store. Scanning produces the so-called 'rolling shutter' effect. The simple test for this is to use a small desk fan, and to adjust the rotation speed such that strobing holds the blades almost stationary. Then, if the sensor is being scanned, the down-ward moving blade will be widened and the upward-moving blade narrowed. The effect is made much more visible by using a short shutter.

Fig. 16 shows a still frame, using 1/1000 shutter. The blades are distorted, but not excessively so. With more normal shutter durations, the effect is much less pronounced.
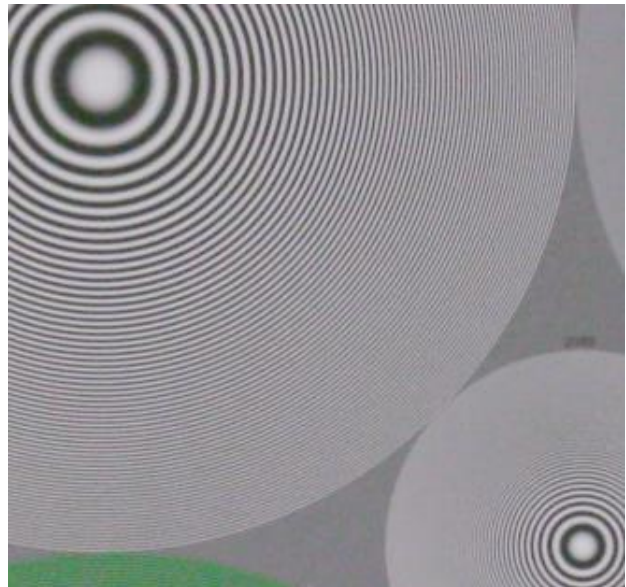
Figure 16: Rolling shutter effect

4. Conclusion

The recording coder bit-rates (up to 410Mb/s) and bit-depths (10 and 12) would qualify the camera for R.118 Tier 1, for both HD and UHD. The sensor size qualifies it for Tier 1 but UHD requires full resolution (3840x2160) in each of RG and B. Therefore the camera can qualify for Tier 1 in HD but only for Tier 2 in UHD.

Noise levels are good, the camera easily qualifies for Tier 1 in HD, and for Tier 2 in UHD provided the Canon Log 2 setting is used. With noise reduction set at not more than 5, the qualification holds up to ISO6400 (30dB gain), and the levels of aliasing drop virtually to zero. Dynamic range is very good - the Canon Log 2 settings deliver up to 15 stops, Canon Log delivers about 13.5 stops, BT.709 delivers about 11 stops.

Although the correspondence between ISO and Gain settings sets the base level of 0dB gain at ISO 200, the specifications refer to ISO 800 when dealing with noise and sensitivity. At ISO 800 and 1/50 shutter, the sensitivity is between F/10 and F/11 when using BT.709 preset, F/10 for Canon Log and F/9 for Canon Log 2 – this is to produce 50% video level with 18% reflectance lit at 2000 lux.

Infra-red response is negligible.

Motion portrayal can be affected by the 'rolling-shutter' scanning, but is a problem only with very short shutter durations.

Overall, the camera qualifies for R.118 Tier 1 in HD and Tier 2 in UHD.

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