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

Alan Roberts, July 2017

SUPPLEMENT 26: Assessment of a Canon XC15 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 XC15 camera, serial number 193294000115, a European version. It is clearly a development of the Canon XC10, resembling a small DSLR rather than a conventional television camera, but has an integral lens and no monocular viewfinder. However, a monocular viewfinder can be simulated by using an accessory mirror-box adaptor on the LCD touch-screen display, but this prevents access to some control functions which are operated only on the touch-screen.

According to the specification, the sensor is a single large-format CMOS with the Bayer pattern of photo-sites; 8.29Meg for video (3840x2160), 12Meg for stills (4,000x3,000), and nominally 1" size. Further information from Canon reveals that the full sensor is 4224x3164, actually 16.8mm diagonal. Thus the full sensor dimensions are 13.48x10.10mm and the photo-sites are spaced at 3.192 microns, giving a photo-site area of 10.19 square microns, about 40% of that of a conventional ⅔" camera. The video image (both 4k and HD) is made from a central 3840x2160 part which must be 12.26x6.89mm and 14.1mm diagonal. The effective photo-site size for HD is 6.38 microns square, similar to that of a conventional ⅔" camera.

The lens is fixed (not inter-changeable) with a 10:1 zoom range effectively 27.3 to 273mm for video, 24.1 to 241mm for stills (35mm equivalent). Maximum aperture is F/2.8 and ramps to about F/5.6 at the long end of the zoom. It has a manual zoom ring and a focus ring which is disabled in 'auto-focus' mode, so is not calibrated.

All recording is MXF format 8-bit MPEG4 AVC/H.264 4:2:2. HDTV recording is onto SDHC card (long-GoP, at 50Mb/s for 50P, 35mB/s for 25P or 25I), 4k recording is onto CFast card (3840x2160 intra-frame at 305Mb/s for 50P, 205Mb/s for 25P). Recording can also be done 'off-speed' between 4 and 1/1200 times normal, and there's a 5-second cache for pre-recording (only in HD).

The camera weighs 1kg with the internal battery (7.2v) and consumes 6W when recording 4k, 5.5W when recording HD. The removable battery is 1.865Ah (14Wh) so should last at about 2.5 hours in normal video use. The battery can be charged in the camera or in an external charger.

There are connectors for HDMI output (disabled when Wi-Fi is enabled), USB for file transfer, 3.5mm microphone, 3.5mm headphone.

Controls include three assignable buttons. The right-hand side hand-grip can be swivelled up to ±90°.

Monitoring is done on a 3" LCD panel of 'approximately 1,030,000 pixels' (about 64x43mm, implying about 1240x830 pixels). It can be swivelled up or down nearly 90° and the image can be enlarged 2:1 for focusing. Most of the camera control is via this display as a touch-screen, although the system controls are via a menu system driven by buttons on the hand-grip. Since the touch-screen is capacitative, it responds only to fingers, not finger-nails or styli. Also, the accessory mirror-box prevents access to the screen.

An optional audio module has XLR input and outputs and manual controls.

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Many of the menu items have little or no effect on image quality. Those that have significant effect are highlighted. Control of the camera is split between 'proper' menus and item-by-item control from the touch screen. In boxes with a range of numeric settings, the values indicate the range, and no scales are given. Default settings, where known, are underlined. Only settings relevant for video shooting are listed here, although many operate for video shooting, replaying and photo modes. All measurements were made using Manual mode.

The tested camera was an E version which has items related to 50Hz, the U version (NTSC) has items related to 59.94Hz and drop-frame timecode. Only the E version is covered here.

In the tables, items that have an important effect on picture appearance are highlighted with grey background. There are very few differences from the XC10. Rather than making recommendations for settings, I have included measurement results from which the user can make his own decisions.

This is not intended as a replacement for reading the manual.

1. Switches, Connectors and Menu settings

Switches and connectors

Left side	Focus	Manual/auto switch
	Disp. (Assign 1)	Cycles screen info
	Push AF (Assign 2)	Find auto focus
	Mic	3.5mm stereo input
	HDMI out	Video, disabled if WiFi enabled
	USB	Computer connection
	Power	
Handle top	Start/Stop	Traditional red button
	Photo/Video	Mode switch
	Wheel	Assignable rotary control
	On/Off	Power button
	Play	Playback start/stop
	Shooting mode dial	Manual, Av (aperture priority), Tv (shutter priority), P (program AE), Auto, Scn (special scene)
Handle back	Magnify (Assign 3)	LCD enlarger, x2
	Menu button	
	Menu joystick	
Handle right	Headphone	3.5mm stereo output
Bottom back	Memory card slots	
	Battery compartment	

Menu settings

Access by menu button or touch screen. Select/set via joystick or touch or drag relevant part of the screen. Submenus are indented.

Camera setup

Item	Mode	Range	Description
Face detection & tracking	MAvTvPScn	<u>On</u>, Off	Not tested
Auto slow shutter	PAv	On, <u>Off</u>	Blurs in low light
ND filter	All	On, <u>Off</u>	3 stops, x1/8
Flicker reduction	All	Auto, <u>Off</u>	Reduce lighting flicker

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AE Lock	All	N (Normal), H (Highlights)	
Auto ISO limit or AGC limit	AvTvP	Auto, ISO or Auto, dB	Set max ISO160~4000 or Gain 0dB ~ 28.5dB
Shockless WB	All	On, Off	
Onscreen markers	All	Off, Level (white), Level (grey), Grid (white), Grid (grey)	Level is mid-high horizontal, Grid is 3x3
Focus ring direction	All	Normal, Reverse	
Focus ring response	All	Fast, Normal, Slow	
AF Speed	All	Fast, Normal, Slow	
ISO/Gain	All	ISO, Gain	Changes some menu items
Gain increment	All	Normal, Fine	
Shutter speed mode	All	Speed, Angle	
Rolling shutter reduction[1]	All	On, Off	

Recording setup

Item	Mode		Range	Description
4k/HD	All		4k clips, HD clips	Also on screen, bottom left
4k recording	All		25p/305Mb/s, 25p/205Mb/s	
HD recording	All		50p/50Mb/s, 50i/35Mb/s, 25p/35Mb/s	
Slow & Fast motion[2]	All	4k	Off, x2, x4, x10, x20, x60, x120, x1200	Also on screen, bottom right
		HD	Off, x1/4, x1/4, x2, x4, x10, x20, x60, x120, x1200	
Available space in memory	All		Reports on cards	
Initialize	All		CF, SD	Format memory cards
Timecode mode	All		Preset, Regen	
Timecode running mode	All		Recrun, Freerun	
Initial timecode	All		hh:mm:ss:ff	Set the timecode
User bit type	All		Setting, Time, Date	
Camera index	All		A~Z	
Reel number	All		001~999, Reset	
Clip number	All		001~999, Reset	
User defined	All		5 characters A~Z 0~9	
Color bars	All		Off, EBU, SMPTE, ARIB	
1kHz tone	All		-12dB, -18dB, -20dB, Off	Tone with bars
File numbering	All		Reset, Continuous	

Audio setup

Item	Mode	Range	Description
Input ½	All	On, Off	
CH 2 Input	All	Input 2, Input 1	For mono recording
Input 1 mic trimming	All	+12, +6, 0dB, -6, -12	
Input 1 mic att	All	On, Off	
Input 2 mic trimming	All	+12, +6, 0dB, -6, -12	
Input 2 mic att	All	On, Off	
Input 1/2 ALC link	All	Linked, Separated	
Input 1/2 limiter	All	On, Off	
Mic att	All	On, Off	
Mic low cut	All	On, Off	
Built-in mic att	All	On, Off	
Built-in mic low cut	All	LC2, LC1, Off	
Built-in mic sensitivity	All	Normal, High	

[1] Rolling Shuuter Reduction item is in the manual but not found in the camera on test.

[2] Slow & Fast recording is not quite what it seems, e.g. x1/4 means recording 4 times over-speed, and setting 50p at 50Mb/s the camera will run at 25p and recording is at 18Mb/s. Beware, check other settings such as shutter speed to make sure that recordings will be sensible.

Monitor channels	All	Ch1/Ch2, Ch1/Ch1, Ch2/Ch2, Ch1+2/Ch1+2	
Headphone volume	All	0~8~15	
Speaker volume	All	0~8~15	
Notification sounds	All	High, Low, Off	Beeps for self-timer etc

Wi-Fi setup

Item	Mode	Range	Description
Browser remote	All	Off, On	Must be Off to enable HDMI
Browser connection settings	All	Set camera ID and port	
Smartphone connection	All		Read the manual
Access point connection	All		Read the manual
Display MAC address	All		

System setup

Item	Mode	Range	Description
Language	All	For the menus (English)	Lots of languages
Time zone/DST	All	Lots of cities (Paris)	Also Summer time On, Off
Date/Time	All		
Date/Time	All		Enter date and time
Date format	All	YMD, MDY, DMY	MDY in U version
24 hour	All	Select	Changes time to am/pm or 24h
LCD brightness	All	Horizontal scale	Shows greyscale to help
LCD backlight	All	H, M, L	
View assistance	All	On,Off	Realistic monitoring of C-Log
Auto power off	All	On, Off	5 minutes to auto power-off
Assign button 1 Assign button 2 Assign button 3	All	Disp, Push AF, Magnification, Zebra, Peaking, Digital tele-conv, Powered IS, ND filter, Start/stop, Photo, Waveform monitor	Default is 1=Disp, 2=Push AF, 3=Magnifcation
Control Dial	All	Iris, Shutter, ISO/Gain	Rotary control near Start/Stop
Customize FUNC menu	All	Iris, Shutter, ISO/Gain, AWB, Mic Level, Exposure lock, AE shift, Zebra, Peaking, Powered IS	Set 10 items from the list
Fan	All	Auto, On	The fan is very quiet
Wireless remote control	All	On, Off	
Tally lamp	All	On, Off	
Battery info	All	Display battery info	
HDMI timecode	All	On, Off	
HDMI rec command	All	On, Off	
HDMI status	All	Display only	
Distance units	All	Metres, Feet	
Backup menu settings	All	Save, Load	Saves menu to SD card
System Frequency	All	50, 24Hz	Changes other items
GPS auto time setting	All	Off, Auto update	
GPS information display	All	Display	
Rec touch operations	All	On, Off	
Output on-screen displays	All	On, Off	
Certification logo display	All	Display	
Firmware	All	Display	
Reset all	All	No, Yes	Full reset

Touch screen controls Submenus are indented.

Item	Mode	Range	Description

FUNC				Vertical list, right-hand side
Iris	MAv		F/2.8~F/11	In ¼ stop steps. Max aperture reduces with zoom
Shtr	MTv		½~1/50~1/2000	Shutter, 4 steps per factor of 2
ISO/GAIN[3]	M	Look 1,2,4 ISO	160~20000ISO	ISO stops 3 steps per factor of 2, GAIN in 1.5dB steps
		Look 1,2,4 GAIN	0~42dB	
		Look 3,5 ISO	500~20000ISO	
		Look 3,5 GAIN	9~42dB	
WB	MAvTvPScn		Automatic, Daylight, Shade, Cloudy, Fluorescent, Fluorescent H, Tungsten, K, User 1, User 2	White balance. K can be set 2000 to 15000. User setting are auto
Mic level	MAvTvPScn		Auto, Manual	Manual can be set 0~100
Exposure lock	AvTvPScn		Manual, Off	Manual can be set -3~+3 stops in ¼ steps
AE shift	AvTvP		-2~0~+2	Stops in ¼ steps
Zebra	All		Off, 70,100	70%/100%
Peaking	All		Peak, Peak off	Make sharp edges red in LCD
Powered IS	All		On, Off	Image stabiliser
Digital tele-conv[4]	All		On, Off	X2 lens magnification
Focus[3]	All			Touch spot to focus
Magnification[3]	All		Off, On	Touch to select area

FUNC			Vertical list, left-hand side
Look/Scn[5]	MAvTvP	1 Standard, 2 EOS Std, 3 Wide DR, 4 Cinema EOS Std, 5 Canon log, User 1, User 2	2 is too vivid, 5 needs post
	Scn	Portrait, Sports, Night, Snow, Beach, sunset, lowlight, Spotlight, Fireworks	
Audio scene	All	Standard, Music, Festival, Speech, Meeting, Forest & birds, Noise suppression, Custom	
Metering mode	AvTvP	Standard, Spotlight, Backlight	
Self-timer[6]	All	Off, 2 sec, 10 sec	
Image stabilizer	All	Off, Standard, Dynamic	
Pre Rec[7]	All	On, Off	5 second pre-rec

Other FUNC controls

Item	**Mode**		**Range**	**Description**
HD/4k	All		4k clips, HD clips	Bottom left of screen
Slow & Fast motion[1]	All	4k	Off, x2, x4, x10, x20, x60, x120, x1200	Bottom right of screen
		HD	Off, x1/4, x1/4, x2, x4, x10, x20, x60, x120, x1200	

[3] Noise is good up to 6400ISO (31.5dB) but the picture softens significantly above 1600ISO (19.5dB)
[4] Item not available unless specifically added via 'Customize FUNC menu'
[5] Standard has good knee for general purpose shooting, EOS Std is too vivid, 3 4 and 5 have a more gentle knee for a film-type look
[6] Self-timer appears in the menu list but could not be enabled in the tested camera.
[7] Pre-recording is available only in HD recording.

2 Measurements

All measurements were made on frames captured onto a SDHC card for HD, CFast card for 4k. Images for this document were extracted as BMP files or LZW-compressed TIF files using Edius 8.31. I shall use the EBU system of designating scanning standards. Live viewing was done on a 50" consumer grade LED Panasonic display (50DX750, 3840x2160, HDMI input) with 'studio' settings.

2.1 Colour performance

A standard Colorchecker chart was exposed, using tungsten. The camera was allowed to auto-white balance and to auto-expose. Fig 1 shows the performance for the nine standard 'Looks'.

Figure 1 Colorchecker, P50, 9 'Looks'

1 Normal	2 EOS Standard	3 Neutral	4 EOS Cinema	5 EOS Cinema (off)
6 Canon log	7 EOS Std (Vivid…)	8 Wide DR	9 Highlight priority	

Look 1 (Normal) is good for normal television use,
Look 2 (EOS std) is a little less saturated,
Look 3 (Neutral) is very like Look 1,
Look 4 (EOS Cinema "Production matrix") is very desaturated,
Look 5 (EOS Cinema "Matrix off") is less desaturated,
Look 6 (Canon log) is low contrast and under-exposed as expected,
Look 7 (EOS standard "vivid, sharp, crisp") is quite livid and over-saturated,
Look 8 (Wide dynamic range) is desaturated and nice for a film look,
Look 9 (Highlight priority) is under-exposed, defending highlights, possibly a little too much so.

Choosing the right Look is a personal matter, but Looks 1 and 3 are fine for normal TV without further processing, Look 5 (Canon Log) is very good for a film look and should match other cameras with log curves. Look 8 (Wide DR) is somewhere between 1 (Normal) and 6 (Canon Log) and needs post-production work. All the Looks are acceptable but post-production using any of them may bring problems with noise and/or saturation levels, since recording is only 8-bit.

There was no response to infra-red, clearly there must be an IR-stop filter in the optical path. This augurs well.

2.2.Resolution and aliasing

2.2.1 Resolution for 4K (actually UHD-1)

Tests were made at F/5.6. 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.

Fig.2 shows one quadrant of the luma pattern which now reaches the 3840x2160 limits of UHD-1, plus one quadrant of the smaller pattern which now reaches the 7680x4320 of UHD-2. The recording was intra-frame at 305Mb/s, using Looks 3, 4, 5 and 8. Only the contrast differs between these examples.

As in the XC10, the modulation is extinguished above 3000 horizontally, and 1700 vertically. There is fairly strong diagonal aliasing which is inevitable with a Bayer-patterned sensor. There is no evidence of any

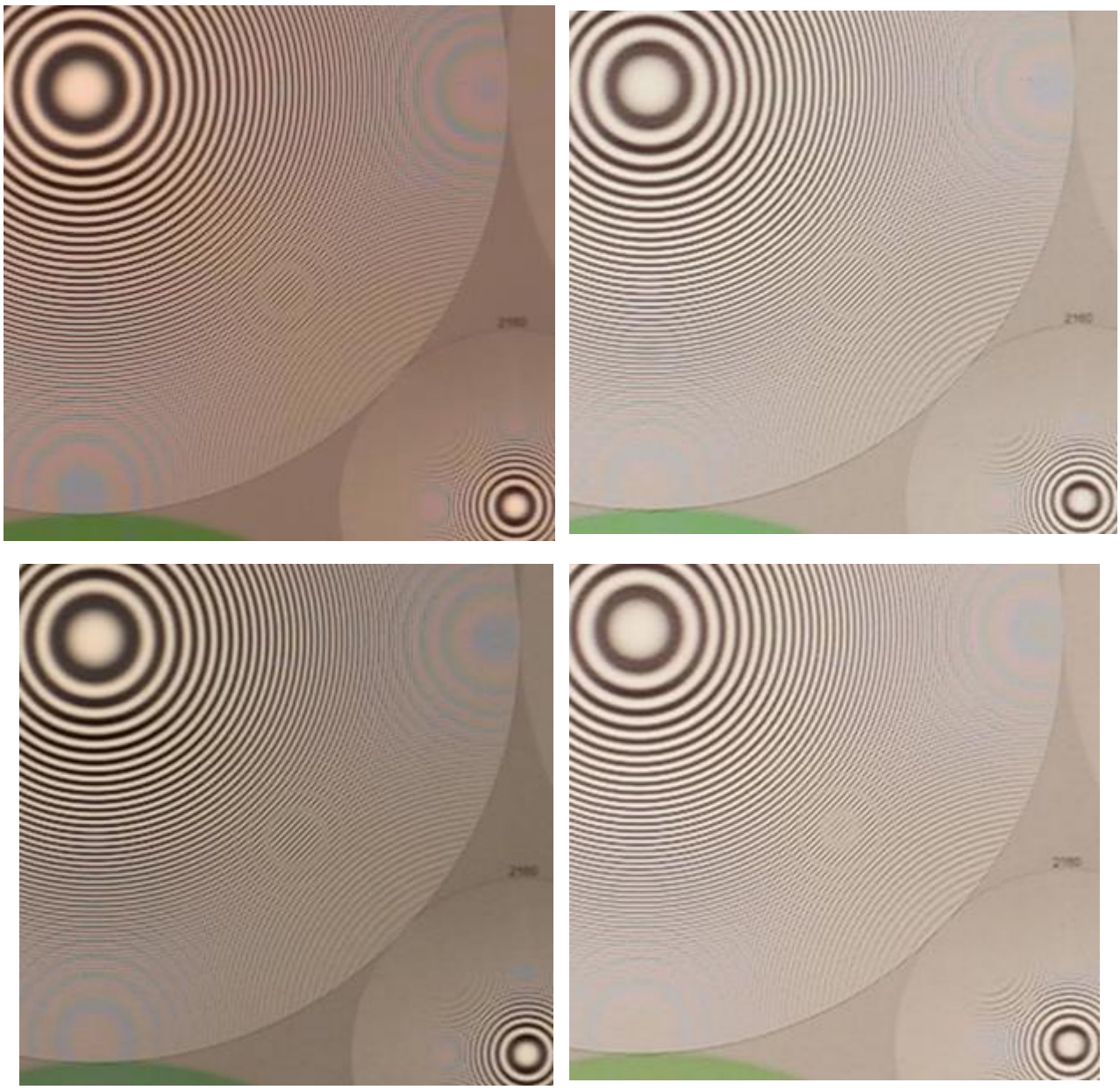

Figure 2 Zone plate, resolution at 4K (actually UHD-1)
Look 3: Neutral
Look 4: EOS Cinema "Production matrix"
Look 5: EOS Cinema "Matrix off"
Look 8: Wide dynamic range

aliasing above the limits of UHD-1, therefore either the lens cannot resolve it or there is an optical low-pass filter tailored to the limits of UHD-1.

Interestingly, the diagonal resolution appears to exceed both horizontal and vertical extinction limits. This implies that the Bayer-decoding is the limit, rather than the optics, which in turn suggests that there is probably no optical low-pass filter and it is the lens which is providing the spatial filtering.

Clearly, there is a considerable drop in resolution with the wide dynamic range looks, and the alias levels have dropped dramatically as well. However, the actual resolution in Look 5 only just exceeds the limits of HD, and while it is likely that post-processing would restore much of the resolution loss the alias level would probably also rise.

Fig. 3 shows quadrants of red and green, Look 3. The red pattern resolution is little different from the green, which confirms that resolution is limited by the lens.

The

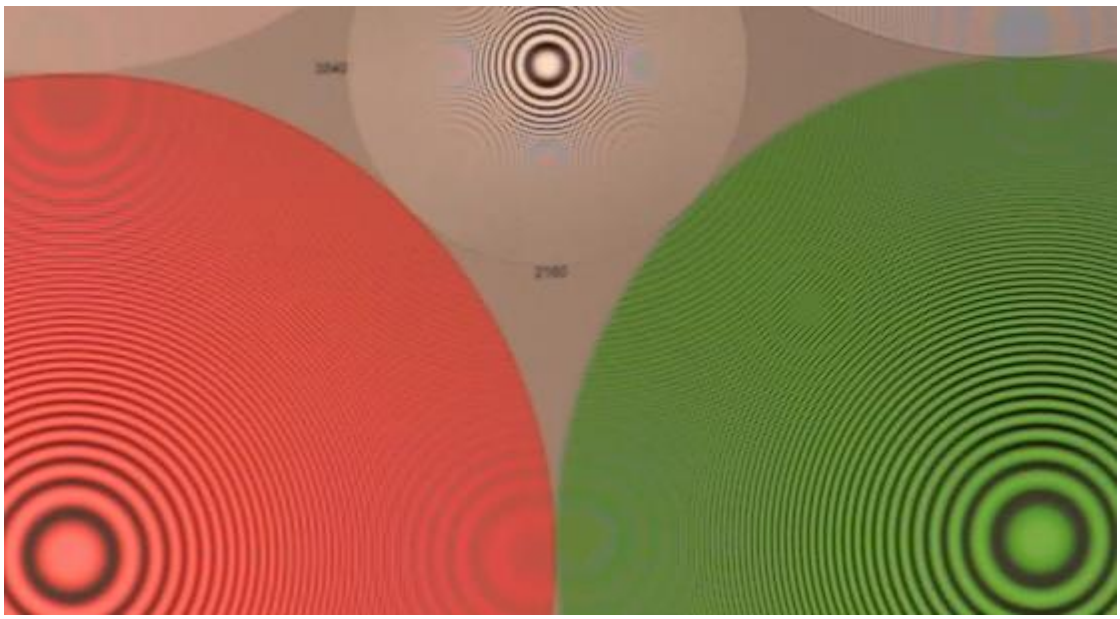

Figure 4 Zone Plate, resolution at UHD-1, red and green patterns

resolution performance is acceptable for EBU R.118 classification in Tier 2 for UHD-1, although 10-bit output is required for full compliance and so this camera should strictly not be accepted for UHD broadcast at all. Aliasing levels are acceptably low.

Figure 3 Zone plate, resolution HD, Look 3, Neutral

2.2.2 Resolution for HDTV

Exposures were made at F/6.7. 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 (if there is one) 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. 4 shows luma quadrants in p/50 with sharpness set to minimum, zero, and using Look 3, described as Neutral. The main quadrant reaches 1920x1080, 3840x2160 in the smaller pattern. The level of aliasing is reasonably low. Vertical resolution is similar to horizontal, but there is evidence (in the smaller pattern, exploring UHD resolution) that the down-scaling process is not ideal, where aliasing is visible beyond the

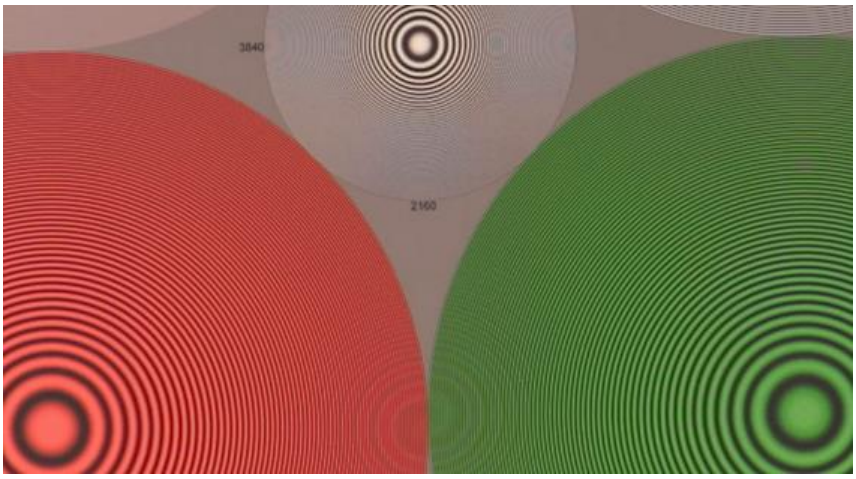

Figure 5 Zone plate, resolution at HD, Look 3, Neutral, red and green

resolution limits of HD.

Fig. 5 shows red and green quadrants. Since the image is from the compressed video there is no reason why the red pattern should not have the same resolution as the green. There is a difference but it is quite small; resolution appears to be symmetrical. Resolution is quite acceptable.

Fig 6 shows the luma part of the chart with detail set to the minimum value 0, and to maximum 7. All the previous figures used the default sharpness setting of 3.

Figure 6 Zone plate, resolution at HD, Look 3, Neutral
Sharpness = 0 Sharpness = 7

The default value seems a good compromise between aliasing and resolution, while the maximum setting is clearly not acceptable for good HD. Note that the maximum setting also brings up aliasing beyond the limits of HD, which will cause problems with motion in MPEG coding. This also shows that the optics do not block frequencies beyond HD.

As for UHD, the Look affects the apparent resolution. The Cinema and wide dynamic range looks (4,5,6,8)

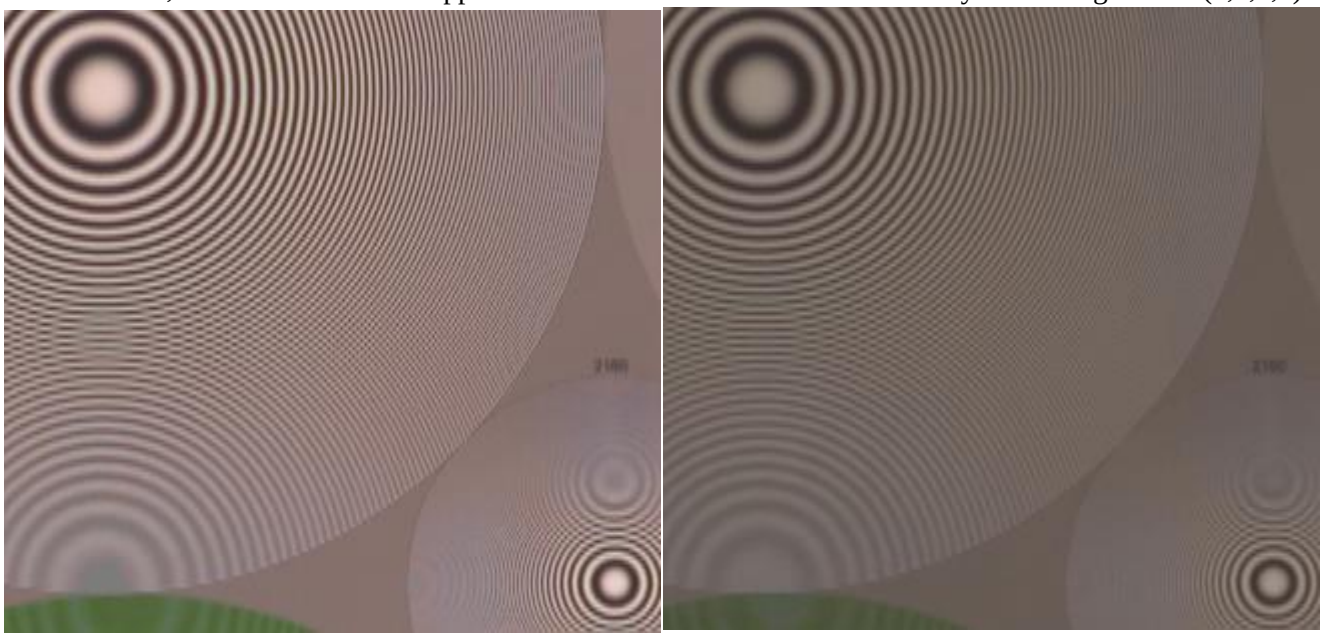

Figure 7 Zone plate, resolution at HD, interlaced
Look 3: Neutral Look 6: Canon log

are soft, while the video looks (1,3,9) are sharper, the others are in-between.

Fig. 7 shows the resolution for interlaced HD, with standard sharpness and Looks 3 and 6. The re-sampling process which generates the interlaced output does not filter out the vertical components sufficiently to avoid serious vertical aliasing. Otherwise, resolution is the same as for progressive capture.

2.3 Gamma Curves and Noise

2.3.1 HDTV

The camera was exposed to a 6-step grey scale, tungsten illuminated. Multiple exposures were taken to explore the dynamic range at ISO800, shooting HD. These exposures were used to derive the gamma curves and noise measurements.

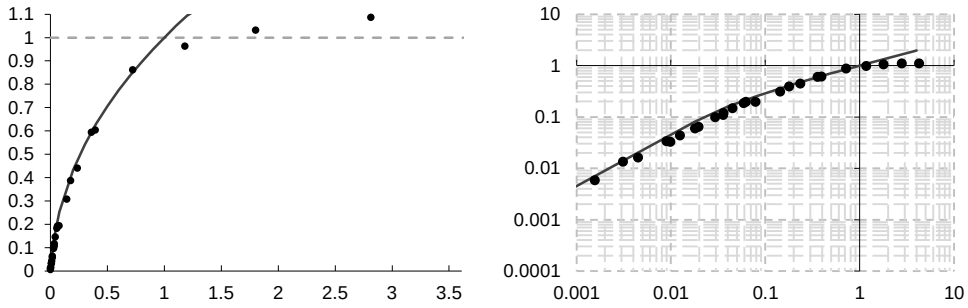

Figure 8 HD, Gamma curve, Look 1: Normal
Linear scales Log scales

Fig. 8 shows the gamma curve: the solid line is the standard ITU R.709 HD gamma curve for comparison. There appears to be about 2 stops of headroom, dealt with by a built-in knee from about 90% video level. This is good for normal television shooting.

Figs. 9 and 10 show the gamma curves for Looks 6 and 8, Canon log and Wide dynamic range. Both are intended for shooting when post-production will be involved. While both appear to capture the same dynamic range, Look 6 appears to be based on the Cineon film curve, thus it should match other professional cameras with 'log' curves. Look 8 has a steeper slop and so should render skin tones more accurately, and produce pictures which appear to be a little brighter. However, use of either curve with only 8-bit capture imposes a limit on the amount of post-production manipulation is possible before colour-quantising becomes visible.

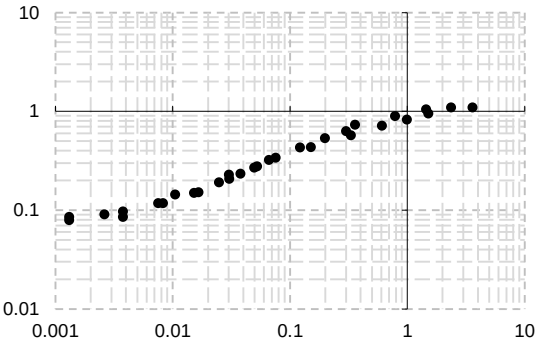

Figure 9 HD, Gamma curve, Look 6 Canon log

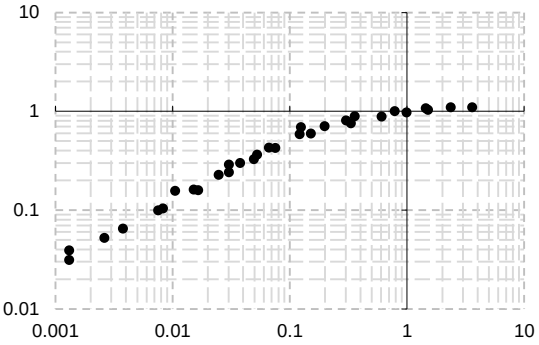

Figure 10 HD, Gamma curve, Look 8 Wide DR

Fig. 11 shows the noise profile (noise level versus video signal level) for Look 1.

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 consistently. This indicates that, at low levels, the noise levels are largely dominated by photon noise (also known as 'shot noise'), which is proportional to the number of photons being intercepted. At high levels, the droop in noise is consistent with the ever-reducing gain of the gamma-corrector.

The level at 50% video is better than -51dB, easily beating the -48dB qualifying level for EBU R.118 HD Tier 1. However, since the noise level falls from this level towards black, the pictures look significantly less noisy than these figures imply.

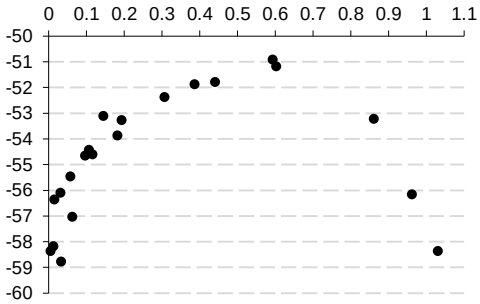

Figure 11 HD, Noise profile, Look 1

The noise levels using the other Looks are different, mostly

lower, but are likely to return to the levels of Look 1 after post-processing to produce acceptable pictures. Thus, Look 1 can be used to characterise the noise performance of the camera irrespective of the Look used.

Next, the camera was exposed to achieve 50% luma level over the full range of ISO settings. Exposure was controlled using the shutter and iris. Fig. 12 shows the results for Looks 3 (Neutral), 6 (Canon Log) and 8 (Wide DR), plotting the noise level versus the ISO setting expressed in dB, with 0 being ISO 800.

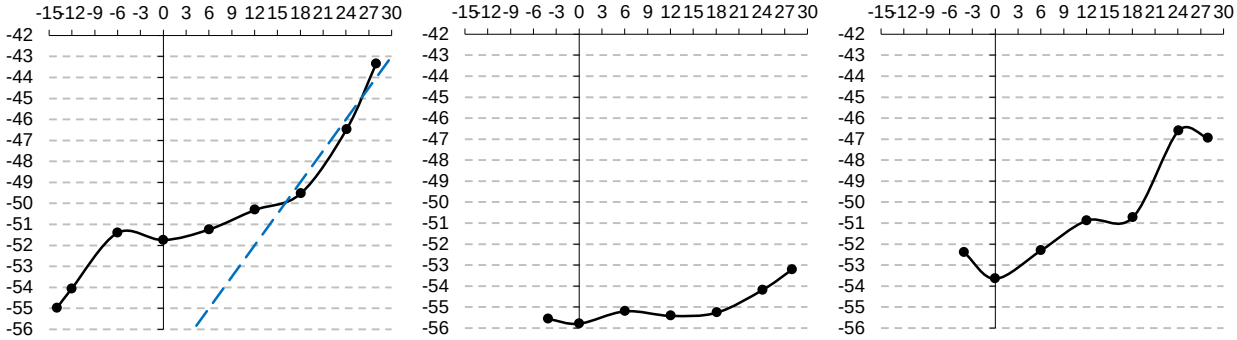

Figure 12 HD, Noise level versus Gain
Look 3: Neutral Look 6: Canon Log Look 8: Wide DR

The 'normal' curve for this test would be a linear slope, rising by 3dB in noise level with each 6dB in gain, as in the blue dotted line. The deviation from this ideal indicates that either there is some signal processing, probably noise reduction, going on which is one of the possible reasons for the unconventional shape in Fig. 9, or that there is a noise floor around -55dB due to the 8-bit quantisation. Nevertheless, the target noise level of -48dB is held up to 20dB gain, which is the equivalent of ISO 10,000.

Look 3 is most representative of the camera. The Looks designed to capture more dynamic range have a different noise performance, because the gamma curves are different. Canon Log delivers much lower noise, but the noise will largely return when the necessary post-processing is done. One possible reason for the unusual noise levels could be a change in resolution with ISO setting. Fig. 13 shows this using Look 1. The drop in resolution is visible, but only notable at high gain, ISO 6400 and above, so this isn't the reason.

Figure 13 Softening with gain, HD, Look 1 Normal
ISO 160 ISO 800 ISO 6400

2.3.2 UHD

Gamma curves are the same for HD and UHD.

Fig.14 shows the noise profile for Look 6, Canon Log. It is very similar to that for HD, but with a greater droop at high signal levels as is expected for a log-type curve. It easily meets the EBU R.118 target of -52dB, although the necessary post-processing is likely to raise noise levels significantly.

Fig. 15 shows the relationship between gain and noise, at 50% video level in Look 6. The curve follows the expected slope of

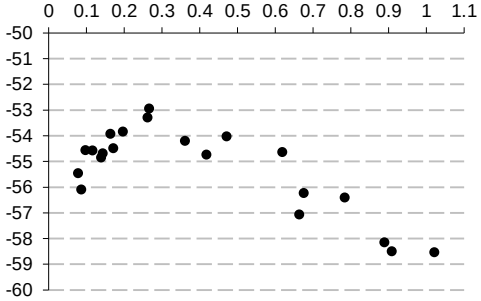

Figure 14 Noise profile, HD, Look 6

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.

3dB noise per 6db gain quite nicely at high gain, but indicates that there is a noise floor in the camera at low gains. The camera reaches the R.118 target of -52dB at up to 15dB gain (relative to ISO800, i.e. ISO4,000) and -48dB at up to 27dB gain (i.e. ISO16,000). However, it should always be born in mind that wide dynamic range gamma curves are less noisy than conventional gamma curves, and that some of this noise advantage disappears after post-production.

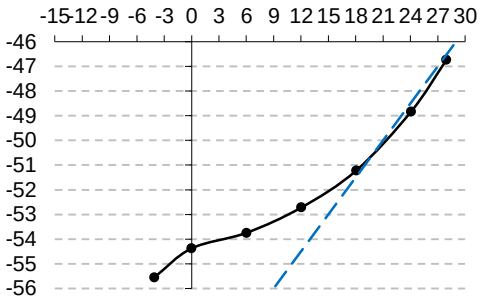

Figure 15 UHD, Noise versus Gain at 50%

Again, some softening should be expected at high gain levels. Fig. 16 shows the resolution at ISO400, 6,400 and 20,000. Clearly, the resolution drop is much more significant at UHD than at HD, to the extent that at ISO 6400 the resolution does not meet requirements for HDTV, let alone UHD. The acceptable limit is somewhere around ISO 1600.

Figure 16 Resolution loss at high gain, UHD, Look 6 Canon Log
ISO 400 ISO 6,400 ISO 20,000

2.4 Dynamic range and Sensitivity

2.4.1 HDTV

For dynamic-range measurements, multiple exposures were made of a Colorchecker chart at ISO 800 using Look1, Look 6 and Look 8, aiming to record exposures at which the white patch was just clipped, and the black patch only just discriminable. This measurement is rather subjective, and may be pessimistic by up to one stop.

For Look 1 (Normal) exposures are not quite clipped over a range of 562:1, or about 9.2 stops, of which about 2.1 stops is headroom, dealt with by the in-built knee.
For Look 6 (Canon Log) the range is about 1142:1, 10.2 stops.
For Look 8 (Wide DR) the range is about 1146:1, 10.2 stops.

So, although the wide dynamic range gamma curves give flatter images, they generally don't capture much more scenic dynamic range compared with the conventional gamma curves. The best dynamic range is between 10.2 and 11.2 stops. This is to be expected in an 8-bit capture system, capture would have to move to 10-bit to improve the dynamic range.

Sensitivity is conventionally measured as the lens aperture (or rather the T number) at which the camera reaches peak white when exposed to a card with 89.9% reflectance, lit by 2000 lux.

For Look 1 (Normal) this is F/8.9.
For Look 6 (Canon Log) it is F/5.1.
For Look 8 (Wide DR) it is F/6.6.

These figures are quite normal for a camera with photo-sites of about 3.1 µm square (10.2 µm^2) , compared with the 5 µm square (25 µm^2) of a conventional ⅔" 3-sensor HDTV camera. The differences between the looks is largely attributable to the slope of the gamma curve near white, making it difficult to identify the precise exposure at which the camera clips.

2.4.2 UHD

For Look 6 (Canon Log) the range is about 899:1, 9.8 stops. So there is little or no difference between HD and UHD as far as dynamic range is concerned.

UHD sensitivity is the same as for HDTV.

2.5 Motion effects

The sensor has a conventional 'rolling shutter' process for readout, and so differentially distorts objects moving in the frame. Fig. 17 shows parts of two frames from a sequence of a small desk fan, the blades rotating such that they appear to be almost stationary. The distortion is quite obvious, and cannot be corrected. This level of distortion is not unusual in cameras with a rolling-shutter.

Figure 17 Rotating fan

The manual for the camera states that there is rolling shutter compensation, the final item in the 'Camera Setup' menu. However, this item was missing from the camera under test. It is not clear whether the tested camera was a pre-production model or not – it's Firmware version was 1.0.0.0 and I was told by people at Canon that it was a production model. Something's wrong here.

3 Conclusion

The recording coder bit-rates qualify the camera for all Tiers in R.118, however, the bit-depth is problematic. The camera cannot officially qualify for R.118 UHD-1 because the recording is only 8-bit, whereas R.118 requires 10-bit or greater. Also, R.118 demands interchangeable lenses for UHD-1. Nevertheless the noise performance meets the criteria for both Tiers of UHD-1, and the 4k mode is a good way to shoot for HD production provided extreme speed settings are not used.

The 4k resolution is limited by the optics, and there is some diagonal aliasing. Resolution drops significantly at higher gain settings (ISO settings).

The HDTV resolution and aliasing is good enough for the camera to qualify for R.118 HD Tier 1, as is the noise level and recorded bit-rate. It is only the bit-depth, monitoring and connectivity requirements which are not fully met. Thus its performance meets Tier 1, and it easily meets Tier 2L. It could be used in Tier 1 situations provided the monitoring and connectivity problems can be dealt with.

There is no infra-red response, implying the presence of an IR-stop filter. Motion portrayal is affected by the sensor rolling-shutter. Rolling-shutter compensation is supposed to be included in this camera, but could not be found in the menus of the sample tested.