

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

Alan Roberts, August 2017

## **SUPPLEMENT 24 rev 1: Assessment of a Canon 5D Mark IV 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 the performance of a Canon 5D camera (Mark IV), serial number 023021002310.

It is a large-format (full-frame 35mm, 36x24mm) DSLR camera with interchangeable lenses, Canon EF mount. According to the specification, the sensor has a Bayer pattern of photo-sites; about 30.4Meg and with an aspect ratio of 3:2, therefore it must be about 6750x4500. Thus the photo-site dimensions must be about 5.33 $\mu$ m square, slightly larger than for a conventional 3-sensor  $\frac{2}{3}$ " HDTV camera, so sensitivity and noise performance ought to be very similar.

Video recording is 4K (4096x2160) and HDTV (1920x1080), with frame rates of 24/25/50/100Hz or 23.98/24/29.97/59.94/119/9Hz depending on settings. Recorded bit-rates can go up to 500Mb/s for 4K.

The camera weighs about 900g with the internal battery (7.2v, 14Wh) but without lens. It runs for about 70 minutes while recording on the LP-E6 battery. The battery must be charged externally. There is an optional 'DC coupler' which can power the camera.

There are connectors for HDMI output (disabled when Wi-Fi is enabled), USB3.0 for file transfer, 3.5mm microphone, 3.5mm headphone. There are 17 control buttons which can be customised via the menu.

Monitoring is done on a 3.2" LCD panel of 'approximately 1.62 million dots' (implying about 1558x1038 pixels, but this is the count of R G and B pixels).

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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 found when the camera is set for video shooting are listed here, although many operate for video shooting, replaying and photo modes. All measurements were made using Manual mode. The menu contents listed here come from examination of the camera rather than the manual, which is rather confusing over whether items refer to still- or movie-shooting.

In the menu listing, I have included only items found in the camera when in Video mode, and then only when in 'For PAL' mode. Some items are different in 'For NTSC' mode, e.g. 59.94Hz and drop-frame timecode.

In the tables, items that have an important effect on picture appearance are highlighted with grey background. Rather than making recommendations for settings, I have included measurement results from which users can make their own decisions.

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

#### **1. Switches, Connectors and Menu settings**

##### **Switches and connectors**

Front left	DoF preview button	Press
Front right	Terminal	Remote control connector
Left	Power on/off	
	Mode dial	
	Flash socket	
	Mic socket	3.5mm
	Headphone socket	3.5mm
	HDMI socket	
	USB3.0 socket	
Back	Menu	Button
	Info	Button
	Shooting	Live view -Movie shooting - Start/stop
	Multi-controller	Menu joystick
	AF area select	Button
	Display	Button. Creative Photo/Comparative playback
	Rate	Rating button
	Playback	Movie playback
	Erase	Button
Right	Card slots	CF and SD

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

##### **Menu settings**

<b>Movie shooting 1</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Image quality	(RAW/MRAW/SRAW) – L~S3	Resolution levels

Image review time	Off, 2 sec, 4 sec, 8 sec, Hold	
Beeper	Enable, Touch to silence, Disable	
Release shutter without card	Enable, Disable	
Lens aberration correction	Peripheral illumination	Enable, Disable
	Distortion correction	Enable, Disable
	Digital lens optimizer	Enable, Disable
	Chromatic aberration	Enable, Disable
	Diffraction correction	Enable, Disable
External speedlite control	Flash firing, E-TTL II metering, Flash sync speed in Av mode, Flash function settings, Flash C.Fn settings, Clear settings	
<b>Movie shooting 2</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Exposure compensation	1/3 and 1/2 stop steps	±5 stops
ISO speed settings	ISO speed, Range for movies, Auto range, Min shutter speed	
ISO speed	Auto, 100 ~ 25600	Steps of 1/3 or 1/2
Range for movies		
Minimum	100 ~ 12800	
Maximum	200 ~ 25600, H(32000), H2(51200), H2(102400)	
Auto light optimizer	Disable, Low, Standard, High	
White balance	AWB (ambience), AWB (white), Daylight, Cloudy, Tungsten, Fluorescence, Flash, Adjust, Kelvin	
Custom white balance		
WB correction	9 levels	
<b>Shooting 3</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Picture style	Auto, Standard, Portrait, Landscape, Fine detail, Neutral, Faithful, Monochrome, User 1~3	
High ISO noise reduction	Disable, Low, Standard, High	Not available in 4K/UHD
Highlight tone priority	Disable, Enable	
Dust delete data	EOS software uses this	
<b>Shooting 4</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Movie servo AF	Disable, Enable	
AF method	Tracking, FlexizoneAF, FlexizoneAF	
Grid display	Off, 3x3, 6x4, 3x3+diag	
Movie rec quality		
MOV/MP4	MOV, MP4	
Movie rec size	4K 25p MJPG (4096x2160 16:11) <sup>1</sup> , FullHD 50p All-I (1920x1080), FullHD 50p IPB (1920x1080), FullHD 25p All-I (1920x1080), FullHD 25p IPB (1920x1080)	
24p	Disable, Enable	
High frame rate	Disable, Enable	
Sound recording	Auto, Manual Disable	
Rec level	Slider	Manual
Wind filter	Disable, Enable	
Attenuator	Disable, Enable	
Movie servo AF speed	Always, During shooting	Only in AF method

<sup>1</sup> Beware, 4K does not mean DCI. The frame has blanked lines top/bottom.

AF speed	-7 ~ +2	FlexizoneMulti
Movie servo AF track sens	Locked on (-3 ~ -1), 0, Responsive (1 ~ 3)	
<b>Shooting 5</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Metering timer	4, 8,16, 30sec, 1, 10, 30min	
Time code		
Count up	Rec run, Free run	
Start time setting		
Manual input setting	hh.mm.ss.ff	
Reset		
Set to camera time		
Movie rec count	Rec time, Time code	
Movie play count	Rec time, Time code	
HDMI		
Time code	On, Off	
Btn function		
Timelapse movie	Disable, Enable	
HDMI display	Picture, Pics no info, Pics no menus	
Canon Log settings	Off, On	
Remote control	Disable, Enable	
<b>AF 1</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
AF config tool	5 presets	
Tracking sensitivity	slider	
Accel/deccel tracking	slider	
AF pt auto switching	slider	
<b>AF 2</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
AI servo 1 <sup>st</sup> image priority	Release ~ Focus	Equal priority slider
AI servo 2 <sup>nd</sup> image priority	Speed ~ Focus	Equal priority slider
<b>AF 3</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Lens electronic MF	Enable after one-shot AF, Disable after one-shot AF, Disable in AF mode	
AF-assist beam firing	Enable, Disable, IR AF assist beam only	
One-shot AF release prior	Release ~ Focus	Focus priority slider
<b>AF 4</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
Lens drive when AF impossible	On, Off	
Selectable AF point	All points, cross type points, 15 points, 9 points	
Select AF area selec mode	7 modes	
AF area selection method	M-Fn button, Main dial	
Orientation linked AF point	Same for V&H, Area+pt, Pt only	
Initial AP pt, AI servo AF	Initial AF pt selected, Manual, Auto	
Auto AF pts sel: EOS iTR AF	EOS iTR AF (face priority), EOS iTR AF, Disable	
<b>AF 5</b>		
<b>Item</b>	<b>Range</b>	<b>Description</b>
AF point selection movement	Stops at AF area edges, Continuous	
AF point display during focus	Selected (constant), All (constant), Selected (pre-AF,focused), Selected AF pt (focused), Disable display	
VF display illumination	Auto, Enable, Disable	
AF status in viewfinder	Show in field of view, Show outside view	
AF microadjustment	Disable, All by same amount, Adjust by lens	
<b>Playback 1</b>		Seems to be only about stills

Item	Range	Description
Protect images		
Rotate image		
Erase images		
Print order		
Photobook set-up		
Image copy		
RAW image processing		
<b>Playback 2</b>		Seems to be only about stills
Item	Range	Description
Cropping		
Resize		
Rating		
Slide show		
Image transfer		
Image jump		
<b>Playback 3</b>		Seems to be mostly about stills
Item	Range	Description
Highlight alert	Disable, Enable	
AF point disp	Disable, Enable	
Playback grid	Off, 3x3, 6x4, 4x4+diag	
Histogram disp	Brightness, RGB	
Movie play count	Rec time, Time code	
Magnification (apx)	1x, 2x, 4x, 8x, 10x, Actual size (from selected pt), Same as last magnify (from ctr)	
Ctrl over HDMI	Disable, Enable	
<b>Setup 1</b>		
Item	Range	Description
Record func+card/folder set	Standard, Auto switch card, Rec separately, Rec to multiple	
Record/play	1, 2	Select the card to record/play
Folder	Select or create a folder	
File numbering	Continuous, Auto reset, Manual reset	
File name	Preset code, User 1, User 2	
Auto rotate	On all, On computer, Off	
Format card	Formats SD/CF cards	
<b>Setup 2</b>		
Item	Range	Description
Auto power off	1, 2, 4, 8, 15, 30 min, Disable	
LCD brightness	Auto (3 levels), Manual (7 levels)	
LCD color tone	1 warm, 2 standard, 3 cool 1, 4 cool 2	
Date/Time/Zone	Set dd.mm.yyyy hh.mm.ss Zone	
Language	25 languages	A challenge if you accidentally set to a language you can't read ☺
Viewfinder display		
Electronic level	Hide, Show	Horizontal
Grid display	Hide, Show	
Show/hide in viewfinder	Battery, Shooting mode, White balance, Drive mode, AR operation, Metering mode, Image quality, Digital lens optimizer, Dual pixel RAW, Flicker detection	Select what to see
Touch control	Standard, Sensitive, Disable	
<b>Setup 3</b>		

Item	Range	Description
Video system	For NTSC, For PAL	
Battery info		Shows battery level etc
Sensor cleaning		
Auto cleaning	Enable, Disable	
Clean now		
Clean manually		
<b>Info</b> button display options	Displays camera settings, Electronic level, Quick control screen. Custom quick control screen	Choose all/any/none
Custom quick control	Start editing layout, Revert layout to default, Clear all items	
<b>Info</b> button LV display options	Live view info switching setting, Histogram	
Histogram disp brightness		
Brightness/RGB	Brightness, RGB	
Display size	Large, Small	
Reset		
<b>Rate</b> btn function	Rating, Protect	5 ratings

**Setup 4**

Item	Range	Description
HDMI frame rate	Auto, 50i, 50p	Different 'For NTSC'
GPS	Disable, Mode 1, Mode 2	
Auto time setting	Auto update, Disable, Set now	
Position update interval	Every sec, 5s,10s,15s,30s, Every min, 2m, 5m	
GPS information display		Show where we are
GPS logger	Disable, Enable	
Transfer log data to card		
Delete log data		

**Setup 5**

Item	Range	Description
Multifunction lock	Main dial, Quick control dial, Multi-controller, AF area selection button, Touch control	
Custom shooting mode (C1~C3)		
Register settings	C1, C2, C3	
Clear settings		
Auto update set	Disable, Enable	
Clear all camera settings	Cancel, OK	
Copyright info		
Display copyright info		
Enter author's name	Text entry	
Enter copyright details	Text entry	
Delete copyright information		
Certification log display		Show logos
Firmware ver		
Camera	Ver.1.1.0	
Lens	Ver.1.0.2	

**Function 1 Exposure**

Mostly to do with stills

Item	Range	Description
Exposure level increments	1/2, 1/3	2 or 3 steps per stop
ISO speed setting increments	1/2, 1/3	2 or 3 steps per stop
Bracketing auto cancel	On, Off	
Bracketing sequence	0-+, -0+, +0-	
Number of bracketed shots	3, 2, 5, 7	
Safety shift	Disable, Shutter speed/Aperture, ISO speed	
Same exposure for new aperture	Disable, ISO speed, ISO speed/Shutter speed, Sutter speed	

**Function 2 Exposure**

Mostly to do with stills

<b>Item</b>	<b>Range</b>	<b>Description</b>
Set shutter speed range		
Lowest speed	30sec ~ 1/4000sec	
Highest speed	15sec ~ 1/8000sec	
Set aperture range		
Max aperture	1 ~ 64	
Min aperture	1.4 ~ 91	
<b>Function 3 Display/Operation</b>		Mostly to do with stills
<b>Item</b>	<b>Range</b>	<b>Description</b>
Warnings in viewfinder	When mono is set, When WB is corrected, When one-touch img qual set, When NR is set, When HDR is set	All/any/none
LV shooting area display	Masked, Outlined	
Dial direction during Tv/Av	Normal, Reverse direction	
Custom button controls	Shutter, AF-ON, AE lock (*), DoF preview, Lens AF stop, M-Fn, Set, Main dial, Quick control dial, Multi-controller, AF area selection button, Default set	Set custom buttons. Options not the same for all buttons
<b>Function 4 Others</b>		Mostly to do with stills
<b>Item</b>	<b>Range</b>	<b>Description</b>
Add cropping information	Off, 6:6, 3:4, 4:5, 6:7, 5:6, 5:7,	
Default erase option	Cancel, Erase	
Retract lens on power off	On, Off	
Add IPTC information	Off, On	
<b>Function 4 Clear</b>		Mostly to do with stills
<b>Item</b>	<b>Range</b>	<b>Description</b>
Clear all custom Func		Rest custom
<b>My Menu</b>		Mostly to do with stills
<b>Item</b>	<b>Range</b>	<b>Description</b>
Add My Menu tab	1 ~ 5	See the manual, pp515~518
Delete all My menu tabs		
Delete all items		
Menu display	Normal, Display from My Menu tab, Display only My menu tab	

## 2. Measurements

All measurements were made on frames captured in the camera onto SDHC card. Live viewing was done on a 50" UHD LCD consumer television display (Panasonic 50DX750). Clips were ingested into Edius 8.31 and images for this document were extracted as BMP files. In all cases, the project resolution was set to match the clip resolution thus avoiding any scaling.

The camera serial number was 023021002310. The lens was a Canon Ultrasonic 24~70mm zoom, F/2.8. I shall use the EBU system of designating scanning standards (e.g. 25i is what is commonly called 50i).

### 2.1. Colour performance

A standard Colorchecker chart was exposed, using tungsten illumination. The camera was set to tungsten illumination and 'Picture style' set to each of the options.

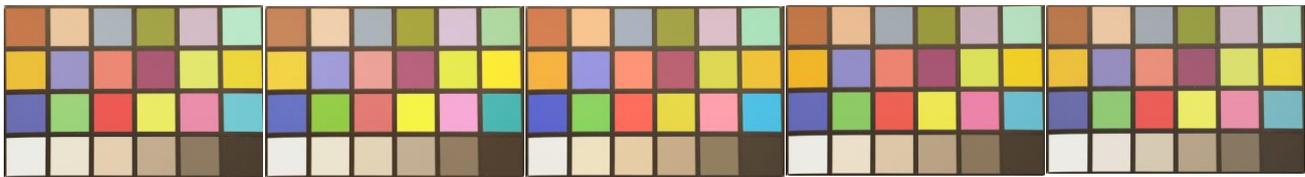


Figure 1 Colour performance, Colorchecker Standard Portrait Landscape Fine Detail Neutral

Figs. 1 and 2 show the results.

Standard, Neutral and Faithful all appear useable for television with post-production, while Portrait, Landscape and Fine Detail might need some work. Canon Log is quite different, and demands post-production work

None of these 'looks' appears to present any problems.



Figure 2 Colour performance, Colorchecker Faithful Canon Log

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

The Colorchecker chart was exposed with tungsten illumination, using the Standard and Canon Log picture styles. Multiple exposures, using shutter and aperture, provided many exposure levels from which it is possible to extract the curves from the grey scale patches. I have assumed that video coding (ITU.601 or 709) is used in the camera, where black level is digital 16, white is digital 235.

Fig. 3 shows the curve for Standard. The solid line is the ITU.709 HD television curve. Evidently, the Standard curve is largely based on the 709 curve, but has a knee which starts at about 80% video level and extending the curve by an additional 150%, about 1/3 stops of headroom.

The dynamic range is the ratio of exposure levels which produce video signals which are not clipped at white, and those which produce signals which are not crushed together near black. In this case, the dynamic range is about 500:1 (because at exposure level of 0.005, there are only two quantum levels separating an exposure change of 2:1, and  $2.5/0.005=250$ ). This is equivalent to 8.97 stops, typical of an 8-bit camera. Taking the lower limit to be 1 quantum per stop, the dynamic range could be 9.97 stops.

Fig. 4 shows the curve for Canon Log. It closely resembles the Cineon curve, which is representative of negative film. The dynamic range in this mode is about 830:1 ( $2.5/0.003$ , because there are only two quantum levels separating an exposure change of one stop at 0.003 exposure). This is equivalent to 9.7 stops. Taking the lower limit to be 1 quantum per stop, the dynamic range could be 10.7 stops. Note that the video signal does not use the full video signal range, white clips at about level 250, while the lowest level recorded during these tests was 33, thus the video signal uses only 217 quantum levels of the 256 available.

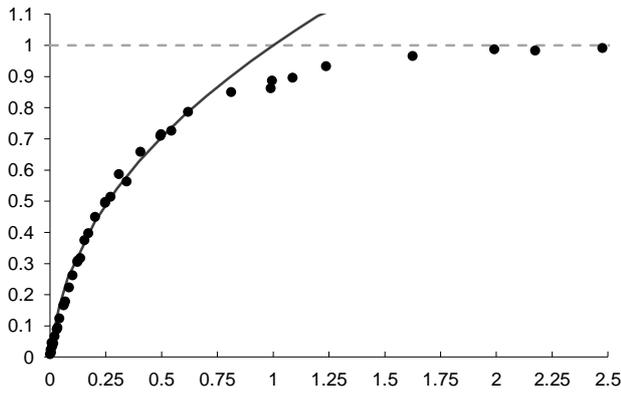


Figure 3 Gamma curve, Standard

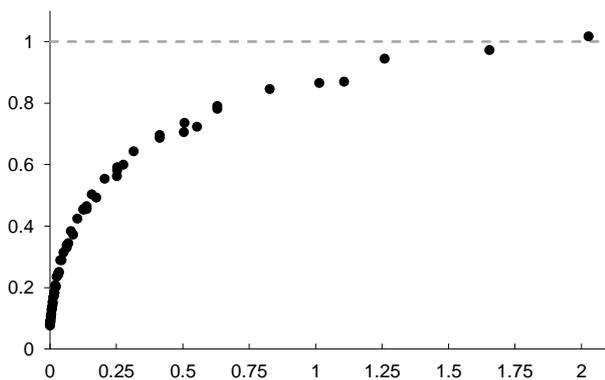
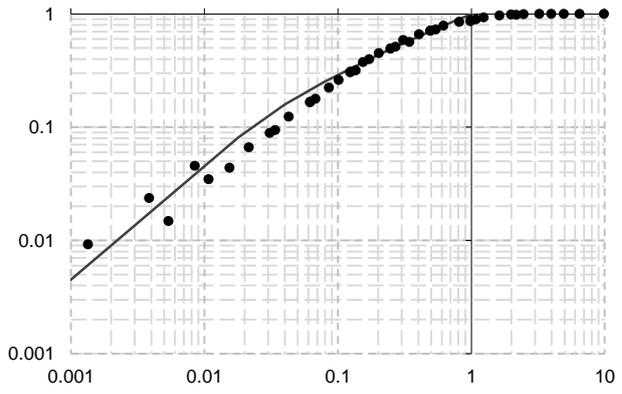


Figure 4 Gamma curve, Canon Log

### 2.3. Resolution and aliasing

The camera does not appear to have a UHD mode, 3840x2160. Only HD (1920x1080) and 4K (4096x2160) are supported. The 4K mode is correctly known as Digital Cinema Image, DCI, but it is described in the camera as 4K. The sensor has about 6750x4500 photo-sites, and it is reasonable to guess that the 4K image comes from an area of about 6144x3240 with a down-scaling factor of 3:2, and that this downscaling can act as a low-pass filter to avoid excessive aliasing. For HD a factor of 3 would be reasonable, meaning that the 1920x1080 image could come from an area of 6760x3240. Again, this down-scaling can act as a low-pass filter.

#### 2.3.1. Resolution for HD

The usual zone plate test chart was framed to fill exactly the width and height of the image. The camera was set to record HD 25p all I-frame, and ISO Standard, ISO400 F/5.6.

Fig. 5 shows one quadrant of the luma pattern which reaches the 1920x1080 limits of HD. Resolution reaches beyond the system limits (at the edges of the larger quadrant) indicating that the down-conversion filtering is not rejecting sufficient of the unwanted higher frequency content. The smaller quadrant is a map of frequencies up to UHD (3840x2160) limits: aliases are clearly visible beyond the HD limits. In theory, with a large, high-resolution sensor, it should be possible to make very good HD images, but the evidence is that the HD image is taken from a windowed section of the

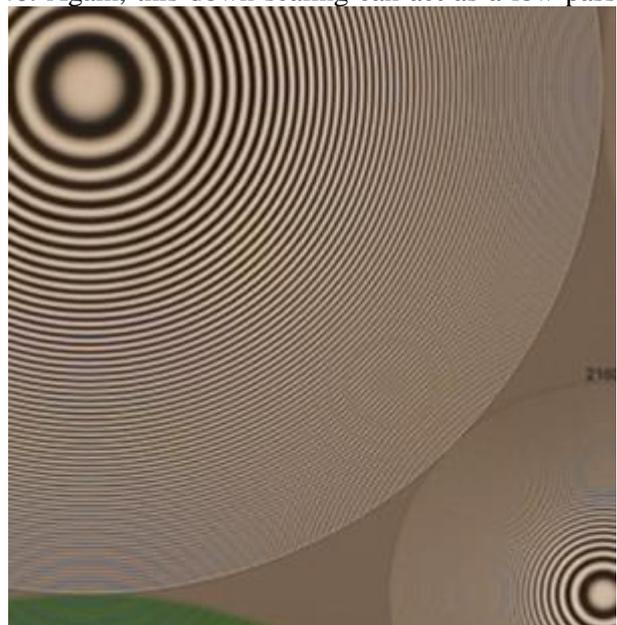
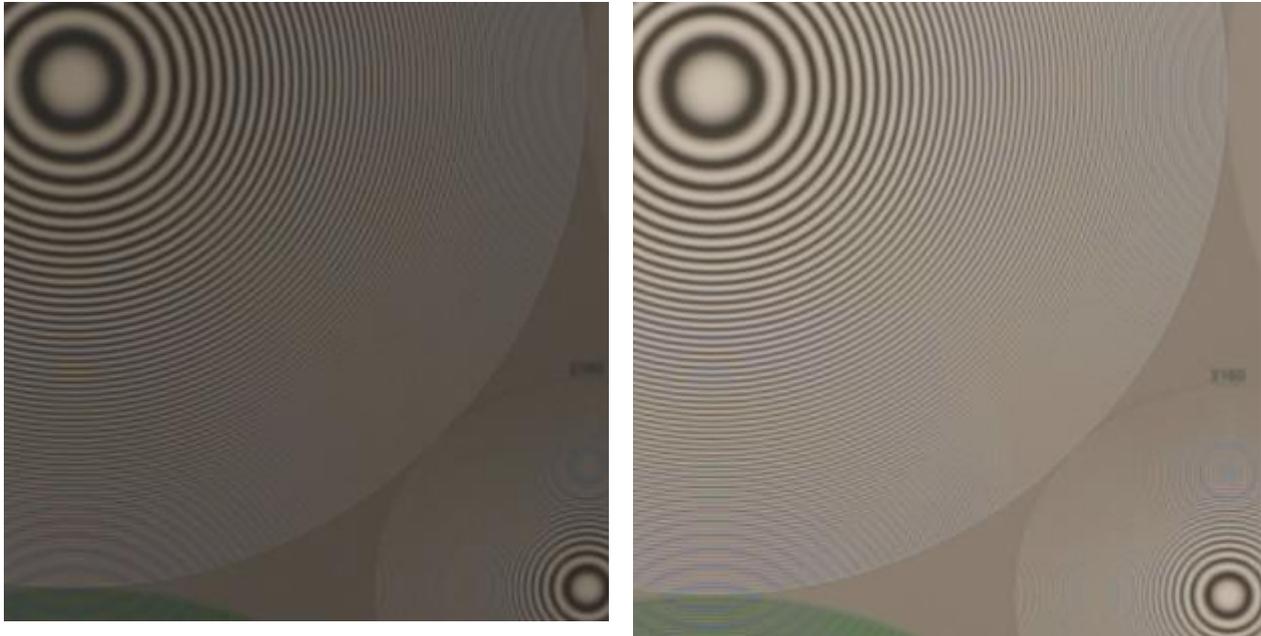


Figure 5 Zone plate, HD ISO 400, Standard, F/5.6

sensor, and does not fully take advantage of the capabilities of such a large sensor. So the potential advantage of a large sensor has not been exploited to reduce aliasing.

Fig. 6 shows the same image recorded using Canon Log. On the left, the exposure is the same as for Fig.5, Standard. Clearly this is underexposed, so the shutter duration was increased by a factor of 4 (2 stops) for the right hand exposure. This is a typical effect of the use of Log curves, the camera appears to be ‘slower’ in ISO terms.

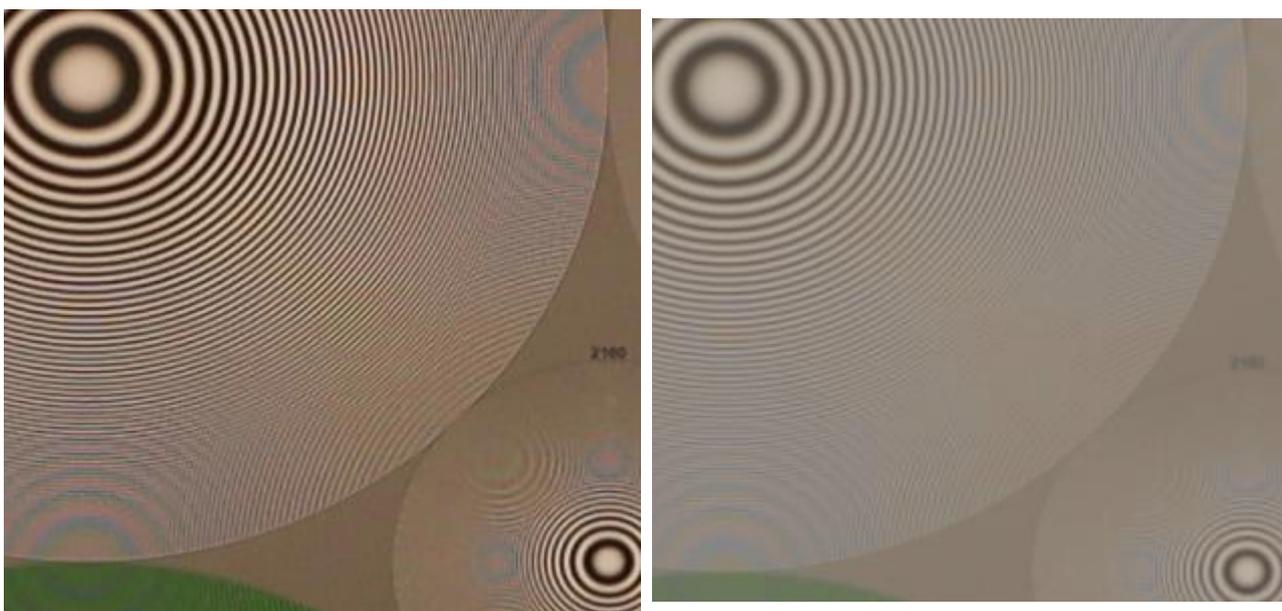


**Figure 6 Zone plate, HD ISO400, Standard, F5.6**

Canon Log is much softer than Standard, because the contrast is compressed by the lower slope of this curve in the middle exposure range. Nevertheless, aliasing is still significant and a potential for video compression (since aliases in an image move against the direction of motion of the lower frequencies, confusing motion-detection algorithms).

**2.3.2. Resolution for ‘4k’ (DCI 4096x2160)**

The HD zone plate chart was reframed so that it filled exactly half the frame width. The camera was set to ISO400 and F/5.6.



**Figure 7 Zone plate, 4K ISO400, F/5.6, Standard**      **Canon Log**

Fig. 7 shows one quadrant of the luma pattern. Again, the resolution is a little greater than it should be in that there are aliases at the pattern edges. The smaller quadrant, now exploring 8192x4320, shows aliases above the limits of 4K, indicating that there may be no optical low-pass filter in the camera and that the aliasing may be due to the high performance of the lens.

The similarities between resolution at 4K and HD are striking, confirming that the HD mode simply uses a 1920x1080 windowed section of the sensor. This confirms that it ought to be much better to record in 4K even if the required resolution is HD, since most editing software can do a reasonably good job of down-conversion.

However, there is a problem with the 4K mode, in that it does not fill the frame with image pixels. Fig. 8 shows frames captured in HD and 4K, each time the width of the test card was made to fill the width as accurately as possible.

**2.4. Resolution change with ISO setting**

The resolution is not constant, it depends on gain or ISO setting. Fig. 8 shows quadrants of the zone plate at ISO400, 1600 and 6400. The drop in resolution is evident but not dramatic. Aliasing is still visible.

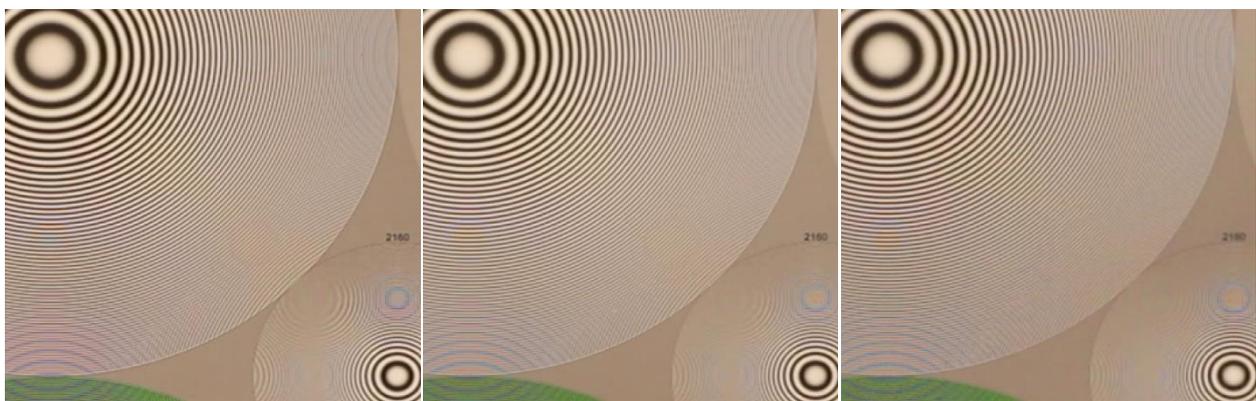


Figure 8 Zone plate, softening with ISO setting, 400, 1600, 6400

**2.5. Noise**

**2.5.1. Noise profile**

The exposures of the Colorchecker used in section 2 were used to measure noise levels in the grey scale.

Fig. 9 shows the noise profile at HD, ISO400, Standard mode.

Conventionally, the noise level is expected to rise as the signal tends towards black. This is because the gamma-correction applies ever-increasing gain towards black. However, photon noise (properly known as shot noise) increases with signal level, which tends to counteract this effect. In this camera, photon noise clearly dominates at low exposure, and the noise levels are quite low anyway.

The EBU R.118 target level for noise at mid-grey (50% signals) is -50dB for UHD (3840x2160), -48dB for HD Tier 1, -44dB for HD Tier 2. The camera clearly meets all these targets in HD mode.

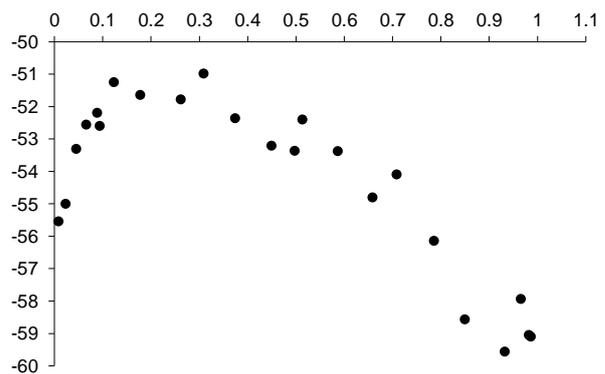


Figure 9 Noise profile, HD, ISO400, Standard

Fig. 10 shows the noise profile for 4K, also ISO400, Standard mode: the noise levels are higher. This is surprising, since the evidence from framing images indicate that HD is formed from a windowed section of the sensor, so HD and 4K noise levels ought to be very similar. The only explanation I can think of is that the down-scaling converter is reducing noise in the HD image.

Noise in 4K mode does not meet the R.118 criterion for 4K, by about 2.5dB: but 4K-shooting would be a good way to get good HD, using a good software down-converter which should also reduce the noise levels.

**2.5.2. Noise change with ISO setting**

Further exposures to the Colorchecker chart were made at the full range of ISO settings, and measurements made to establish the noise level at exactly 50% video signal level. Monitoring was not sufficiently precise to be able to set the exposure correctly, so interpolation was used between the two patches at which the signal level was just above and just below 50% signal level.

Fig. 11 shows the result. The horizontal axis is marked in dB of gain, with zero corresponding to the reference setting of ISO400; thus ISO100 is -12.061dB, and ISO12800 is +30.1dB. The noise should rise by 3dB for each increase in gain of 6dB (or change of 2 in ISO speed).

The straight line has a slope of 0.5, 3dB per 6dB of gain, and shows that the camera noise level is much higher than it should be at low ISO settings. Nevertheless, the target figure of -50dB for UHD is easily met at all ISO settings.

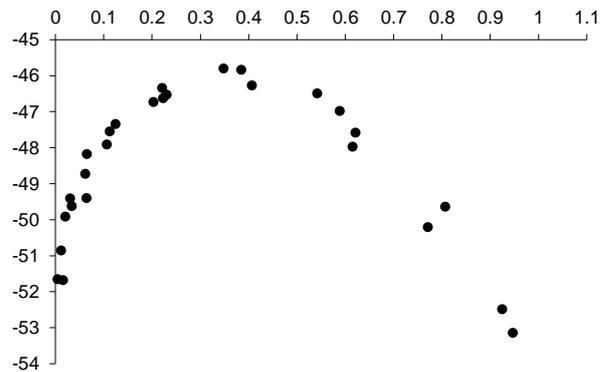


Figure 10 Noise profile, 4K, ISO400, Standard

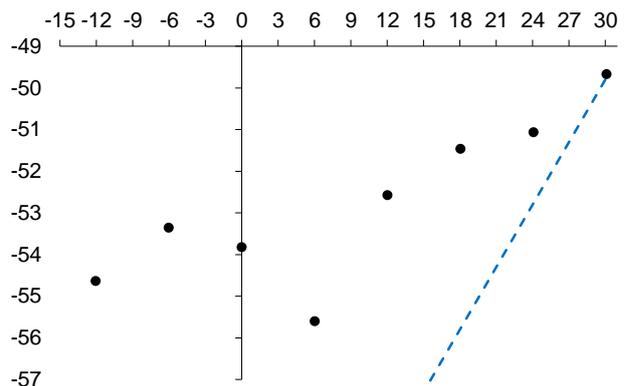


Figure 11 Noise vs ISO, HD, Standard

**2.6. 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. Fig. 12 shows results for measurements at a range of exposure levels.

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. Peak white level is reached (in the luma signal, the black line) at about F/5.5: however, we know that peak white is not reached until exposure level is approximately 250%, relative to a nominal ITU.709 gamma curve. So, the lens aperture which would cause peak white in a conventional ITU.709 gamma curve must be about 1.3 stops further closed down, i.e. about F/6.8.

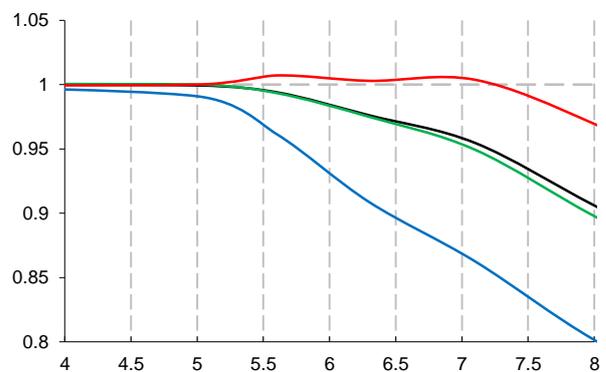


Figure 12 Video level vs aperture, HD, ISO400

**2.7. 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. There was slight response to IR when the camera was overexposed by 4 stops, implying that there is an IR filter in the camera and that IR is not a problem.

**2.8. 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 clockwise 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. 13 shows still frames, in HD and 4K.

The motion distortion is significant but not severe. The effect is clearly visible even at 1/50 shutter although the blades are quite blurred.



**Figure 13 Rolling shutter effect, HD and 4K**

## **Conclusion**

The sensor has about 30.4 megapixels according to the specification, and is approximately 36x24mm, full-frame 35mm stills size. The highest resolution it can record (as a still) is 6720x4480, which is a total of 30,105,600 pixels, and the sensor has an aspect ratio of 3:2, therefore the individual photo-sites must be about 5.35 $\mu$ m square, a little bigger than the 5 $\mu$ m square of a conventional 3-sensor  $\frac{2}{3}$ " HD camera. Rather than use the maximum possible area of the sensor for each resolution it can capture, it appears to use windowed sections for video recording. Thus, the image size changes with resolution setting, and the achieved resolution does not effectively change (the pictures simply change size) and the camera does not make full use of the available resolution.

The 4K format uses about 1.64 times the number of photo-sites as the HD format, horizontally. Vertically, the ratio is about 1.53:1. Thus there is no obvious relationship between the formats, except that HD uses about half the number of photo-sites compared with 4K. The apparent focal length of the lens changes by about 1.53:1 between the two video formats.

Resolution at both 4K and HD contains significant aliasing, performance does not appear to change much between the formats. The level of aliasing may not be too much of a problem in practice unless the lens is 'too good' for the camera.

The dynamic range is around 10.5 stops in Canon Log mode.

Noise levels are good. The camera meets the EBU R.118 noise-level target of -48dB for all HD tiers, but in 4K mode it does not meet the target of -50dB for UHD. However, 4K mode would be a good way to shoot material for use in HD, with down-conversion in post-processing, because the down-scaling will reduce the noise levels acceptably. It cannot formally qualify for Tier 2 for HD simply because of the missing features required by EBU R.118 (connectivity, monitoring, sound facilities etc.). In terms of image performance alone, it could qualify for HD and UHD tier 2 even though the missing features will restrict the practical uses of the camera.

The sensor is evidently scanned, the so-called 'rolling shutter' effect. Rotating motion is not ideal but is acceptable.