Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 50 rev.1 : tests and settings on a Canon XF300/305

Tests were made on a Canon XF305E, serial number 263050000050, after preliminary tests on a prototype model. The camera has 3 1/3" CMOS sensors and an integral lens. It records MPEG2-compressed video, but all the tests were made using the HDSDI output, captured uncompressed and analysed in software.

The 305 model has HDSDI output, can be genlocked, and has timecode connection, while the 300 has none of these connections. Both models are available in 'E' and 'A' versions, working at 50Hz and 59.94Hz respectively. A hardware upgrade can be installed in either to make the camera work at both rates, but tests were made only on an unmodified 'E' (50Hz, PAL) model. The distinction between models is obscure, and is apparent only on the makers label underneath the camera. Casual users would not be aware of these differences.

The camera weighs 2.65kg, which is fairly heavy for a small-format camera. The built-in lens has 18:1 zoom range from 4.1mm to 73.8mm focal length (equivalent to 29.3 to 527mm in a full-frame 35mm camera). The sensors are CMOS, full-resolution 1920x1080. Recording is onto Compact Flash card (two slots) in MPEG-2, long-GoP, with MXF file format. Three bit rate options are available: 50Mb/s CBR (constant bit rate) at 4:2:2 colour sampling (1920x1080 or 1280x720), 35Mb/s 4:2:0 VBR (1920x1080 or 1280x720) and 25Mb/s 4:2:0 CBR (1440x1080 only). Thus it complies with broadcast requirements for bit rate and offers more economic rates for greater economy. At these rates, a 64GB card can record 160, 225 and 310 minutes respectively. In 1080 mode, both interlaced and progressive modes are available. Off-speed recording at fixed speeds from 12 to 60fps is possible.

There is a conventional viewfinder (approximately 1650x935 pixels), plus a separate LCD screen (approximately 1480x830 pixels) front mounted, which can be swung out to either side of the camera. Both displays are adequate for focusing.

There are neutral filters for exposure control, and manual control of the lens. Sensitivity is rather good, although it is specified in an obscure way. On-screen video level monitoring is good, there are options for both waveform monitoring and vectorscope. There is an image magnifier as a focus aid.

Connectivity is good, with HDSDI and timecode (only in the 305 model), plus HDMI and USB, analogue component, BNC analogue video, 3.5mm multifunction jack socket and XLRs for audio. Power consumption is about 9 watts at 7.2 volts.

The camera performed well under test.

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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. "Pref" (preferred) settings are in the last column, where appropriate, for normal video shooting and for film-look shooting. Where no preferred value is given, either the factory setting is best, or the setting does not have great effect on image quality. In some instances, it is possible to alter the menus such that they produce more meaningful numbers. Menus are nested: items in bold-face in the listing are headings leading to a further nested menu.

Camera settings which affect picture quality directly, such as gamma, detail and matrix are held in scene files. These are available via a small button at the back left-hand side of the camera, adjacent to the menu button. Control is simple, with a single rotary control and a 'set' 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 2, after the menus.

This listing of the menus and contents is complete, but this should not be used as an excuse for not reading the manuals.

1 Menus and settings

CUSTOM PICTURE (i.e. scene file)

Main camera settings

Item	*Range*	*description*	*Pref*
Select File	Off, C1~C9, SD1~20	9 scene files, 20 on SD card.[1]	

			Video	Film
Edit file				
Rename	text			
Protect	Unprotect, Protect			
Reset	Cancel, OK			
Gamma	Normal1, Normal2, Normal3, Normal4, Cine1, Cine2	[2]	Normal 3	Cine1
Black				
Master Pedestal	-50~0~+50			
Master Black				
Red	-50~0~+50			
Green	-50~0~+50			
Blue	-50~0~+50			
Black Gamma[3]				
Level	-50~0~+50	+ expands blacks, - compresses	0	
Range	-5~0~+50		0	
Point	-1~0~+50		0	
Low Key Satur				
Enable	On, Off		Off[4]	
Level	-50~0~+50			
Knee				
Enable	On, Off	Highlight compression, not available in Cine gammas	On	
Automatic	On, Off		Off	
Slope	-35~0~+50		[5]	
Point	50~95~109	Lovely, IRE values!	85	
Saturation	-10~0~+10	Preserve colour in highlights	0	
Sharpness				
Level	-10~0~+50		0	-3
H Detail Freq	-8~0~+8		+8	
Coring				
Level	-30~0~+50	To avoid sharpening noise		
D-Ofst	0~50			
D-Curve	0~8			
D-Depth	-4~0+4			
HV Detail Bal	-8~+8		+2	+5
Limit	-50~0~+50		0	
Select	0~15	Aperture correction[6]	+2	+15

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[1] By default, files 1~6 are available for editing, 7~9 protected. 7=factory settings for video shown on consumer displays, 7=film-look on decent monitor, 9=video for printing to film. Protection can be removed for over-writing.
[2] Gamma curves: Normal 1=NHK 4.0, Normal 2=ITU709 4.0 (i.e. the 709 curve with lower slope near black), Normal 3=ITU709, Normal 4=BBC 0.4. Cine 1=film for video, Cine 2=for transfer to film.
[3] Use Black Stretch sparingly, it enhances video noise.
[4] Low-key Saturation helps keep colouring right near black, but can worsen noise, use with care.
[5] Knee was not explored during the tests, because Cine 1 gamma curve is good for a film look. Use Knee Slope to fine tune the video gamma curves if needed, point should be left near 85%.
[6] This appears to be aperture correction, correcting for the basic spatial response or the camera, much more subtle than detail enhancement.

Item	*Range*	*description*	*Pref*	
Knee Aperture				
Gain	0~9		[7]	
Slope	0,1~3		1	
Level Depend				
Level	0~50	Prevent sharpening near black	[8]	
Slope	0~3			
Offset	0~50			
Noise Reduction	1~8, Off, Automatic		Automatic[9]	
Skin Detail				
Effect Level	High, Middle, Low, Off	Soften skin tones		
Hue	-16~0~+16			
Chroma	0~16~31			
Area	0~16~31			
Y Level	0~16~31			
Selective NR				
Effective Level	High, Middle, Low, Off	Fine tune noise reduction[10]		
Hue	0~16~31			
Chroma	0~16~31			
Area	0~16~31			
Y Level	0~16~31			
Color Matrix				
Select	Normal1, Normal2, Normal3, Normal4, Cine1, Cine2	Preset matrices[11]	Normal 3	Cine 1
Gain	-50~0~+50			
Phase	-50~0~+50			
R-G	-50~0~+50		-8[12]	
R-B	-50~0~+50			
G-R	-50~0~+50			
G-B	-50~0~+50			
B-R	-50~0~+50			
B-G	-50~0~+50			
White Bal				
R Gain	-50~0~+50			
G Gain	-50~0~+50			
B Bain	-50~0~+50			
Color Correction				
Select	Off, Area A, Area B, Area A&B	Tweak two colours	Off	
Area A Setting				
Phase	0~31			
Chroma	0~31			
Area	0~31			
Y Level	0~31			
Area A Revision				
Level	-50~+50			
Phase	-50~+50			
Area B Setting				
Phase	0~31			
Chroma	0~31			
Area	0~31			
Y Level	0~31			

[7] Use Knee Aperture gain in conjunction with Knee Slope; as Knee Slope goes down, Aperture Gain can go up, to maintain sharpness.
[8] Use Level Depend in conjunction wit Black Stretch, to prevent over-sharpening near black.
[9] Very effective noise reduction, see measurements section. Setting to 8 reduces resolution to 1280x720 very cleanly, but gives soft pictures, setting to 5 seems to be about right.
[10] Selective Noise Reduction could be useful but will take significant time to set up to be effective.
[11] Same rules as for gamma curves: Normal 1=NHK 4.0, Normal 2=ITU709 4.0 (i.e. the 709 curve with lower slope near black), Normal 3=ITU709, Normal 4=BBC 0.4. Cine 1=film for video, Cine 2=for transfer to film.
[12] Matrix, see measurements section below.

Item	*Range*	*description*	*Pref*
Area B Revision			
Level	-50~+50		
Phase	-50~+50		
Others			
Setup Level			
Level	-50~0~+50	Scales Black and Master Ped	
Press	On, Off	Squeezes video to 100%	Off[13]
Clip 100% IRE	On, Off	Clips hard at 100%	Off
Transfer File			
Copy To	SD1~SD20	Copy current file to SD card	
Load From	SD1~SD20	Copy from SD card to current	
Copy To Cam	C1~C9		
Load From Cam	C1~C9		
Add CP File	C1~C9	Adds file to recording clip	

[13] Press, not tested. This could be handy for shoot-and-run operations where exposure control is difficult.

CAMERA SETUP

Main video standard setting

Item	*Range*	*description*	*Pref*
Light Metering	Backlight, Standard, Spotlight	Auto exposure compensation	
AE Shift	+2, +1.5, +1.25, +1, +0.75, +0.5, +0.25, 0, -0.25, -0.5, -0.75, -1, -1.25, -1.5, -2	Deviation from auto-exposure, stops	
AGC Limit	Off (21), 18, 15, 12, 9, 6, 3dB	Maximum gain AGC will go to	
Gain			
L	Fine tuning, 33, 21, 18, 12, 6, 3, 0, -3, -6dB		-6dB
M	Fine tuning, 33, 21, 18, 12, 6, 3, 0, -3, -6dB		-3dB
H	Fine tuning, 33, 21, 18, 12, 6, 3, 0, -3, -6dB		6dB
Fine Tuning	0~21dB	0.5dB steps, wow!	
White Balance	Daylight, Tungsten, Kelvin	Kelvin sets colour temp. directly	
AF Mode			
Speed	Instant, Normal	Manually tweaking the focus ring overrides auto mode	
Face AF	On, Off	Auto focus on a face	
Focus Limit	On, Off	On sets closest to 1m, off sets to 2cm for macro use	
Image Stabiliser	Powered, Dynamic, Standard, Off	Degree of stabilisation, powered for tripod use, dynamic for walking, standard is lowest.	
Zoom			
Speed Level	Fast, Normal, Slow		
Grip Rocker	Constant, Variable	Variable speed is pressure sensitive	
Constant Speed	1~8~6	Sets constant speeds, 1 (slow)=5 minutes, 1 (fast)=1 minute, 16 (slow)=4.5 sec, 16 (fast)=1.8 sec.	
Handle Rocker H	1~16		
Handle Rocker L	1~8~16		
Wireless Controller	1~8~16		
Teleconverter	On, Off		
Flicker Reduction	Automatic, Off	Compensate for lighting flicker	
Wide Attach Lens	WA-H82, Off	Compensate for wide-angle lens	
Color Bars			
Enable	On, Off		
Type	Type 1, Type 2	SMPTE or ARIB	Type 1[14]

AUDIO SETUP

Item	*Range*	*description*	*Pref*
Audio Input			
XLR Rec CH	CH1, CH1/2		
Int Mic Low Cut	Off, LC1, LC2	1 for voices, 2 for wind cut	
Int Mic Sensitivity	Normal, High	High=+6dB	
Int Mic Att	On, Off	On=-12dB	
XLR1 Mic Trimming	+12, +6, 0, -6, -12dB		
XLR2 Mic Trimming	+12, +6, 0, -6, -12dB		
XLR1 Mic Att	On, Off		
XLR2 Mic Att	On, Off		
XLR ALC Link	Linked, Separate	Use link for stereo recording	
Limiter	On, Off	Limit at -4dB[15]	
1kHz Tone	-12, -18, -20dB, Off	Tone over colour bars	
Audio Output			
Monitor Delay	Line out, Normal	Set headphone sound delay	
Channel	CH1/2, CH1/1, CH2/2, All/All	All does mono mix	
Level	1V rms, 2Vrms	1V=0dB, 2V=+6dB	

[14] Either bars are acceptable. ARIB bars contain more useful aspects than SMPTE, but SMPTE are widely accepted as the standard for HDTV.

[15] Manual audio controls (knobs): 0=off, 5=0dB, 10=+18dB

VIDEO SETUP

Item	*Range*	*description*	*Pref*
SDI Output	HD, SD, Off	Off saves battery power	
Component Output	HD, SD		
HD Onscreen Disp	On, Off	Puts camera screen messages on output, not on recording	
SD Onscreen Disp	On, Off		
SD Output	Squeeze, Letterbox, Side crop		

LCD/VF SETUP

Item	*Range*	*description*	*Pref*
LCD Setup			
Brightness	-99~0~+99		
Contrast	-99~0~+99		
Color	-20~0~+20		
Sharpness	1, 2, 3, 4		
Backlight	Normal, Bright		
VF Setup			
Brightness	-99~0~+99		
Contrast	-99~0~+99		
Color	-20~0~+20		
Sharpness	1, 2, 3, 4		
Backlight	Normal, Bright		
LCD/VF B&W	On, Off	On=mono	
LCD/VF Simul	On, Off	On=v/f and LCD on together	
Metadata Display			
Date/Time	On, Off	Only in playback mode	
Camera Data	On, Off		
Peaking	On, Off		
Select	Peaking 1, Peaking 2	Two settable peaking regimes	
Peaking 1			
Color	White, Red, Yellow, Blue		
Gain	Off, 1~8~15		
Frequency	1, 2, 3, 4		
Peaking 2			
Color	White, Red, Yellow, Blue		
Gain	Off, 1~15		
Frequency	1, 2, 3, 4		
Zebra	On, Off		
Select	Zebra 1, Zebra 2, Zebra 1&2		
Zebra 1 Level	70, 75, 80, 85, 90, 95%	Active over ±5% of target	70
Zebra 2 Level	70~100%	Active above target level[16]	100
HD Output	On, Off	Show zebras on HD video outputs	
Markers			
Enable	On, Off		
Center	White, Gray, Off		
Horizontal	White, Gray, Off		
Grid	White, Gray, Off		
Safety Area	White, Gray, Off		
Select Area	80, 90, 92.5, 95%		
Aspect Marker	White, Gray, Off		
Aspect Ratio	4:3, 13:9, 14:9, 1.66:1, 1.75:1, 1.85:1, 2.35:1		14:9[17]
Audio Level	On, Off		
Custom Display			
Remaining Battery	Warning, Normal, Off	Warning=only when low batt	
Remaining Tec Time	Warning, Normal, Off	and so on	
Rec Mode	On, Off		

[16] When zebra patterns overlap. Zebra 1 takes priority. This is perhaps the best use of zebras I've found in any camera yet.

[17] Not essential, but useful when shooting for mixed 16:9/4:3 delivery.

Time Code	On, Off		
Zoom Position	Always on, Normal, Off	Normal=only when changing	
Light Metering	On, Off		
Custom Picture	On, Off		
ND Filter	Warning, Normal, Off	Normal=only when changing	
Focus Ring Warn	On, Off		
Focus Mode	On, Off		
Object Distance	Warning, Normal, Off	Normal=only when focusing	
Full Auto	On, Off		
White Balance	On, Off		
Exposure	On, Off		
Iris	On, Off		
Gain	On, Off		
Shutter	On, Off		
Wide Attach Lens	On, Off		
Teleconverter	On, Off		
Peaking	On, Off		
Magnification	On, Off		
Image Stabiliser	On, Off		
Interval Counter	On, Off		
SD Card Status	Warning, Normal, Off		
Bit Rate/Resolution	On, Off		
Frame Rate	On, Off		
Character Rec	On, Off		
Wireless Controller	On, Off		
Output Display	On, Off		
SDI Rec Command	On, Off		
User Memo	On, Off		
Audio Output Ch	On, Off		
Audio Level	On, Off		
Date/Time	Date, Time, Date/Time, Off		

TC/UB SETUP

Time-code and User Bits

Item	*Range*	*description*	*Pref*
Timecode			
Mode	Preset, Regen		
Run	Rec run, Free run		
DF/NDF	DF, NDF	Relevant only in 'A' and unlocked 'E' cameras[18]	
Setting	Set, Reset	Opens menu to set TC and UB	
TC In/Out	In, Out	Not available on XF300 models	
User bits			
Rec Mode	Internal, External	Not available on XF300 models	
Output Mode	Fixed, Pulldown		
Type	Setting, Time, Date		

OTHER FUNCTIONS

Item	*Range*	*description*	*Pref*
Reset All Settings	Cancel, OK		
Transfer Menu			
Save To	Menu, Menu+CP	Load save menus, or menus and all custom presets	
Load From	Menu, Menu+CP		
Time Zone	-12.00~+14.00	Default for 'A' model is New York (UTC-5.00)	
Clock Set			
Date Format	YMD, YMD/24H, MDY, MDY/24H, DMY, DMY/24H		
WFM (LCD)			
Setting	WFM, VS, Edge mon, Off		

[18] DropFrame timecode for recording at 'NTSC' speeds (59.94i, 29,97p, 23.98p), is shown as hh:mm:ss.ff, NonDropFrame shows as hh:mm:ss:ff.

Item	*Range*	*description*	*Pref*
Waveform Monitor	Line, Line+spot, Field, RGB, YPbPr	Spot adds waveform for the screen area in the red frame	
Gain	1x, 2x	+6dB gain	
Vectorscope	Spot, Normal		
Gain	1x, 5x	+14dB gain	
Edge Monitor	Type 1, Type 2	Focus aid, shows frequency content	
Language	German, English, Spanish, French, Italian, Polish, Russian, Simplified Chinese, Japanese	Language for screen messages. Menus/settings remain in English	
Wireless Controller	On, Off	Remote control	
Assign Button – Camera mode	:None, Standard IS, Dynamic IS, Powered IS, Focus limit, Face AF, Face select, Backlight, Spotlight, Teleconverter, Peaking, Zebra, WFM (LCD), Magnification, Color bars, Marker, LCD setup, LCD/VF B&W, Onscreen display, Shot mark 1, Shot mark 2, Add OK mark, Add check mark, Time code, Time code hold, Audio output CH, Audio level, Wireless controller, Photo, Rec review, Delete last clip	13 assignables, marked: 1=IS 2=Peaking 3=Zebra 4=WFM 5=Return 6=Magn (right) 7=Magn (top) 8-13 playback buttons	
Assign Button – Media mode	: None, WFM (LCD), LCD setup, LCD/VF B&W, Onscreen display. Shot mark 1, Shot mark 2, Add OK mark, Add L mark, Time code hold, Audio output CH, Audio level, Wireless controller, Photo		
Tally Lamp			
Front	On, Off		
Rear	On, Off		
Media Access LED	On, Off		
Genlock	-1023~0000~+1023	Horizontal phase, XF305 only	
Bit Rate/Resolution	50Mb/s 1920x1080, 50Mb/s 1280x720, 35Mb/s 1920x1080, 35Mb/s 1280x720, 25Mb/s 1440x1080		50Mb/s 1920x1080[19]
NTSC/PAL	NTSC, PAL	Only in unlocked models	
Frame Rate – ‘A’ NTSC	60i, 60p, 30p, 24p, 50i, 50p, 25p	Both models when unlocked	
Frame Rate – ‘E’ PAL	50i, 50p, 25p		
Special Rec	Interval rec, Frame rec, Pre rec, Slow & fast motion, Off	Non-standard shooting	
Interval Rec			
Interval	1~10, 15, 20, 30, 40, 50 sec, 1~10 min		
Rec Frames – ‘A’ NTSC 60i/30p	1, 3, 6, 9		
Rec Frames – ‘A’ NTSC 60p/24p	2, 6, 12		
Rec Frames – ‘E’ PAL	2, 6, 12		
Frame Rec			
Rec Frames – ‘A’ NTSC 60i/30p	1, 3, 6, 9		
Rec Frames – ‘A’ NTSC 60p/24p	2, 6, 12		
Rec Frames – ‘E’ PAL	2, 6, 12		
Slow & Fast Motion			
Rec Frame Rate – 50 or 35Mb/s	12, 15, 18, 20, 21, 22, 24, 25, 26, 27, 28, 30, 32, 34, 36, 40, 44, 48, 54, 60	Variable speed shooting	
Rec Frame Rate – 24Mb/s	12, 15, 18, 20, 21, 22, 24, 25, 26, 27, 28, 30		
Clips			
Title Prefix	AA~ZZ	Text entry	
Number Setting	Set, Reset		
Delete Last Clip	Cancel, OK		
Copy All Clips	Cancel, OK	Copy clips card to card	
Copy OK Clips	Cancel, OK	Copy only OK-marked clips	
Delete All Clips	Cancel, OK	Delete all except OK-marked	
Delete All OK Marks	Cancel, OK	Un-mark all cips	
Rec Review	Entire clip, last 4 sec	Play last 4 seconds of last clip	
Set Metadata			
User Memo	Off, select from files	Requires extra software	
Country Code	4 letters	Entre label, A~Z, 0-9 +-; and space	
Organization	4 letters		
User Code	4 letters		

[19] This is the minimum coding specification accepted for EBU broadcasting at the time of writing (June 2010).

Item	*Range*	*description*	*Pref*
SDI Rec Command	On, Off	Only on XF305	
Photo Numbering	Reset, Continu		
Add CP File			
To Clip	On, Off	Copies settings to clip or photo as metadata	
To Photo	On, Off		
Delete All Photos	OK, Cancel	Wipes the SD card	
Custom Function			
Shockless Gain	Fast, Normal, Slow, Off	Auto gain control	
Shockless WB	On, Off	Auto white tracking	
AE Response	Fast, Normal, Slow		
Iris Limit	On, Off		
I. Ring Direction	Reverse, Normal		
F.Ring Control	Fast, Normal, Slow		
F. Assist B&W	Both, Magnify, Peaking, Off		
Obj. Dist Unit	Meters, Feet		
Zoom Indicator	Bar, Number		
ZR-2000 AE Shift	AE shift, Iris		
Scan Reverse Rec	On, Off		
Character Rec	On, Off		
Reset Hour Meter	Cancel, OK		
Initialization			
CF A	Cancel, OK	Format card	
CF B	Cancel, OK		
SD Card	Complete, Quick		
Firmware		Shows firmware versions	

2 Measurement results

2.1 Colour performance

Assessments were made visually, using Macbeth charts as usual. Performance was generally good, but the skin-tone colours were rather pink. Using the matrix, it was possible to effect some improvement by setting the R-G value to -8, and there may have been more improvements to be gained by spending more time on this assessment, probably setting R-G to a negative value as well, and possibly using the colour corrector. However, the results from the brief test session, using just R-G were quite pleasing and acceptable.

2.2 Gamma curves

There are 4 normal gamma curves available in the camera, and two cine curves. Gamma 1 was clearly the intended factory setting, and initial tests were made using it, but later examinations established that Gamma 3 is the ITU-709 curve and Gamma 4 the BBC 0.4 curve. For broadcast purposes either of these curves is acceptable. Although the BBC curve always produces more accurate colour rendition, the 709 curve is normal for HDTV shooting, so all further tests used Gamma 3.

Experiments with the Knee function established that the camera has about 100% (1 stop) of exposure headroom. While it was perfectly possible to derive settings which would exploit this using standard gamma curves and the knee, it is probably better to use one of the cine gamma curves to achieve a film look.

2.3 Resolution

A HDTV zone plate chart was used. This contains six circular patterns that fully explore the spatial frequency performance of the camera, up to 1920x1080 pixels per width and height. There are patterns for grey-scale testing of luma performance, the others are coloured for examining chroma resolution or other colour filtering. Modulation is cosine rather than square wave. Each pattern is a "phase space" map of the possible frequencies that the camera can be expected to deal with, reaching 1920 pixels/picture width (960 cycles) horizontally, and 1080 lines/picture height (540 cycles) vertically.

2.3.1 Resolution, 1080psf

Fig.1 shows a single quadrant of one pattern; for this exposure, the camera detail enhancement was turned down to minimum level (-10) which presumably means no correction, so this is probably the native performance of the camera. There are clearly no null zones, where the wanted lower frequencies mix with aliases produced by spectral folding of the unwanted higher frequencies, alias products. This is good evidence that the camera has 3 sensors of full 1920x1080 resolution, and that a "quarter-wave" filter (bi-refringent crystal or other fabricated filter) has been included in the optical path, and is well suited to the camera's resolution.

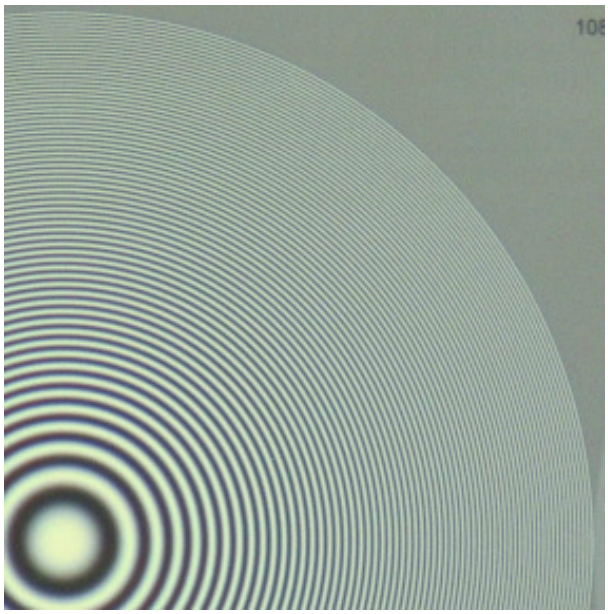


Figure 1, Resolution, 1080psf, minimum detail (-10)

There was no evidence of aliasing caused by out-of-band frequencies in the coloured zone-plate patterns. Usable resolution up to about 900 lines vertically and 1800 horizontally is clear. Also, there was no evidence through aliasing that "precision offset" (the spatial offsetting of the green sensor from red and blue by exactly ½ pixel spacing to improve luma resolution) is used in this camera.

It is rare to see resolution so clearly as this, which is very encouraging.

2.3.2 Detail enhancement, 1080psf

Figure 2 shows the same quadrant with the detail level set to maximum (+50). There are new null zones visible at 2/3 horizontal and vertical resolution limit, which are due to the small deviation of the camera gamma curve from a pure power law (this is third harmonic distortion, emphasised by the detail enhancement), which is a perfectly normal phenomenon.

No new aliases have been produced, but there is a granularity in the higher frequencies caused by the emphasis of video noise. Clearly, this is not a sensible setting value to use, and the camera's 'zero' setting is a good compromise, as is shown in Figure 3. The null zones at 2/3 limiting frequencies are just starting to be visible, but the level is quite acceptable.

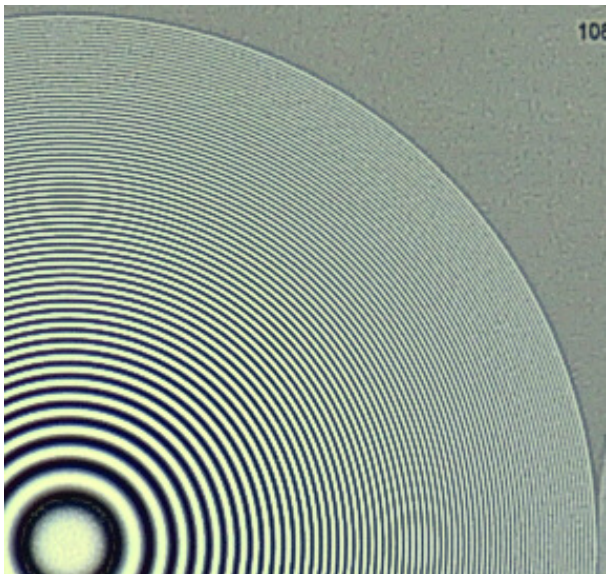


Figure 2, Resolution 1080psf, maximum detail (+50)

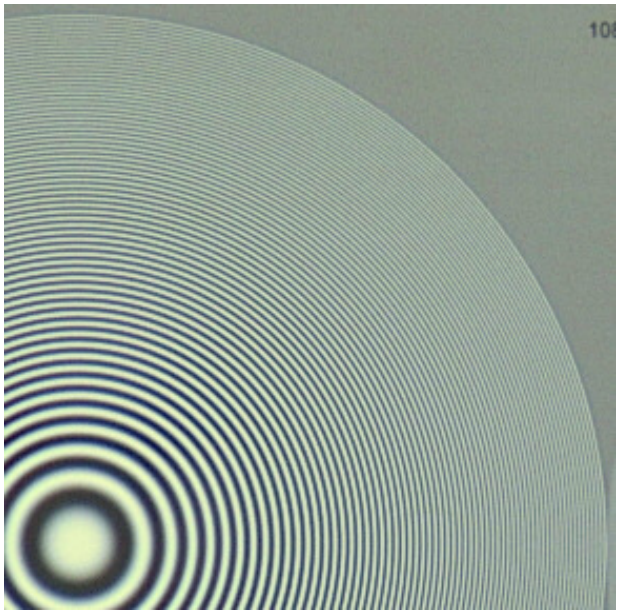


Figure 3, Resolution 1080psf, factory detail (0)

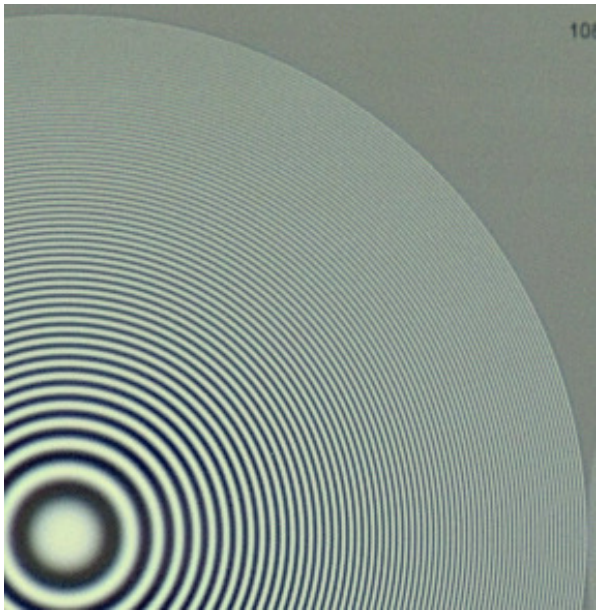


Figure 4, Resolution 1080i, factory detail (0)

2.3.3 Resolution, 1080i

Figure 4 shows the result of setting the camera to interlaced scanning, with the factory detail level setting.

Some vertical detail has been lost as is to be expected from the line-averaging process normally used for deriving interlaced fields, but it has been lost in a clean way, there are no surprises here.

2.3.4 Resolution, 720p

Figure 5 shows the result of setting the camera to 720p/50 mode. Detail settings were those for video use in the menus above. There is a horizontal null zone at 1280 pixels, resulting from the down-conversion process. Ideally, all frequency content above this point should be suppressed, but the filtering used in the conversion process has clearly allowed some of this higher-frequency content through. Vertically, there is a null zone at, and strong aliasing above, 540 lines. This is evidence that the 720p signal is derived from the 1920x1080 signal, rather than by scaling directly from the sensor. This is a little surprising, since the camera has a 1920x1080p/25 mode, which implies that the sensors can be scanned progressively at 25 or 30Hz.

There appeared to be little visible difference between 720p/50 and 720p/25, which, again, is a little surprising.

It appears that the best way to obtain 720p pictures from this camera is to shoot and record in 1920x1080 and then to down-convert as a post-production operation.

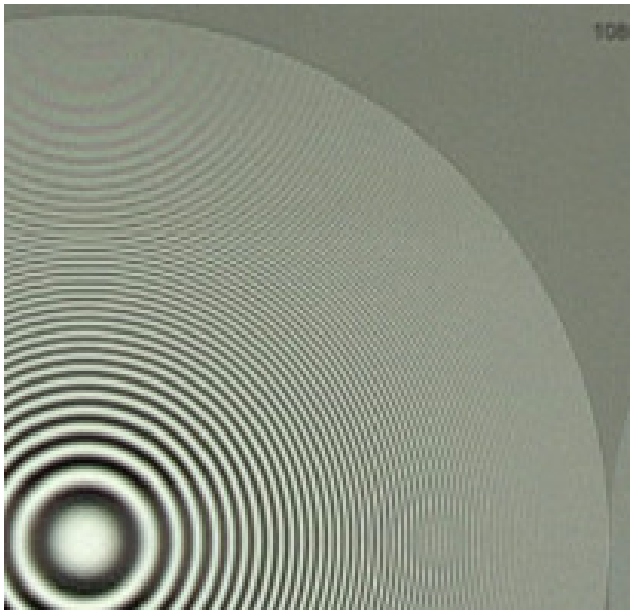
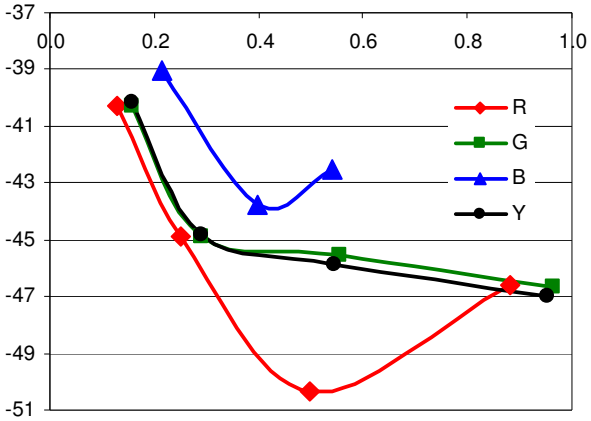


Figure 4 720p resolution, video detail setting

2.4 Video Noise Levels and Sensitivity

Video noise was measured by recording a white card, uniformly lit, and performing numerical analysis in software. The camera was set to +12dB gain to ensure a high noise level for measurement, and the results have been compensated to remove the effect of this higher gain. A high-pass filter was used to remove all horizontal frequencies below about 5% of the nominal maximum of half-sampling frequency.

Two sets of results were obtained, for the camera in default setting, with video noise reduction set to Automatic, and with noise reduction fully off. The noise levels were a little disappointing for a broadcast camera (typically -45.5dB), but are typical for a camera with full-resolution HDTV sensors of 1/3 inch size, and there is little that can be done about it. This value confirms the impression from visual checks made during the test session



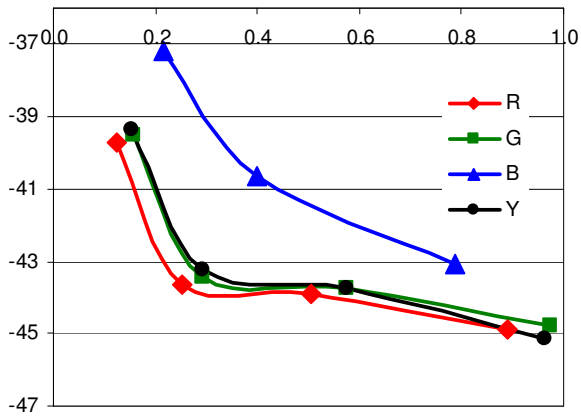
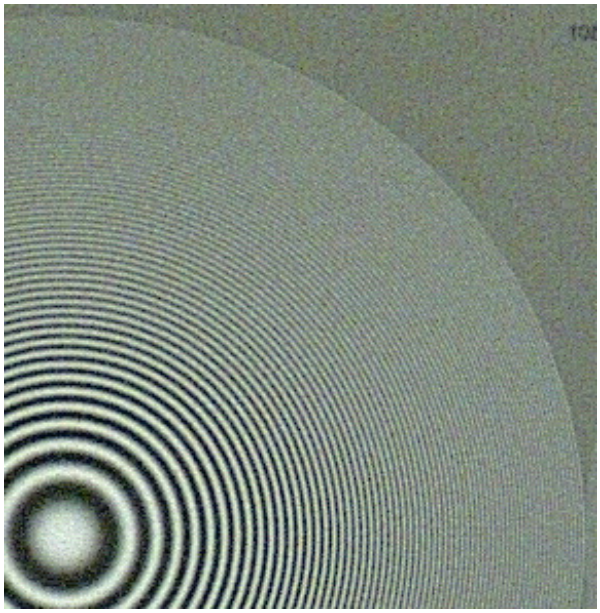


Figure 6, (a) video noise, NR Auto **(b) video noise, NR off**

There is an advantage of about 1.5dB to be gained from using the noise reduction in Automatic mode. However, it should be borne in mind that this advantage is when the camera is set to +12dB gain, and that the advantage will probably be rather less at 0dB gain. Nevertheless, the noise reduction is worth having.

To investigate the noise reduction process itself, exposures were made of the zone plate test chart, at +12dB gain. Figure 7 shows the resolution loss in Auto mode.



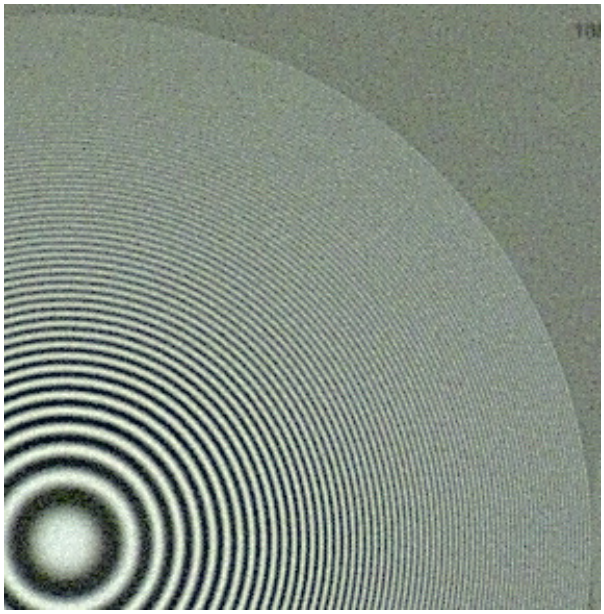


Figure 7, 1080psf, (a) NR Auto, +12dB **(b) NR off, +12dB**

Clearly, little is lost in this mild setting of noise reduction, although some horizontal softening is apparent but not critical. Figure 8 shows the effect of setting the noise reduction to manual, at level 8 (maximum). Here, the resolution loss is dramatic, but still there is no introduction of spurious aliasing. The resulting resolution appears to be nicely limited to a little lower than 1280x720, indicating that the noise reduction process uses both horizontal and vertical filtering, and is done rather well.

Somewhat surprisingly, this control may well be useful as a pre-filter for shooting footage intended for delivery at 1280x720, or for down-conversion to 720x576 SDTV. It should produce results considerably superior to those obtainable through most software down-conversion algorithms, or in-camera down-conversions, because the troublesome higher frequencies are removed at source.

Figure 8, 1080psf, NR maximum (manual, 8)

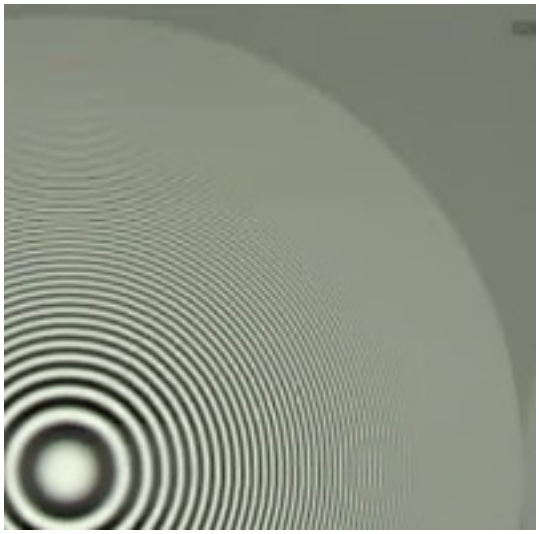


Figure 9, 720p, NR 5

This is an unexpected benefit, which could be of great effectiveness. Figure 9 shows the effect of setting noise reduction to 5 on the 720p performance. The horizontal aliasing beyond 1280 pixels has virtually disappeared, and the vertical aliasing is less pronounced. This seems to confirm that this filtering is done after the down-sampling from 1920x1080 to 1280x720, which is a shame, had it been done before, then the 720p performance would be much better, since the unwanted frequencies would be rejected before the conversion. Setting the noise reduction to 8 visibly softens the 720p picture, probably unacceptably.

If the camera is to be used to deliver 720p pictures, then use of the noise reduction will significantly improve the pictures,

although it is best to shoot at 1920x1080 and then to down-convert as a post-production operation.

Sensitivity was not measured directly. In broadcast cameras, the normal specification would be the aperture setting required to produce full amplitude video when a 90% reflectance card is illuminated with 2000 lux and the camera is set to 0dB gain and normal shutter (e.g. 1/50). The specification claims minimum illumination to be 0.08 lux at 60i, with +33dB gain and ¼ second shutter, and the lens, presumably, wide open (*F*/1.6). Compensating for the long shutter gives a light-level factor of 50/4=12.5, resulting in 1 lux at 1/50. Compensating for the video gain gives another factor of $10^{33/20}$=44.67, resulting in 44.67 lux at 0dB and 1/50. Deriving a further compensation for the open lens to produce an aperture value for 2000 lux illumination finally gives a value of *F*/1.6*√(2000/44.67)=*F*/10.7. So, the sensitivity, expressed in conventional terms is *F*/10.7 for full video at 2000 lux with standard gain and shutter. This is a truly remarkable figure for such a small sensor.

Perhaps the designers would have been better advised to reduce the head amplifier gain by about 6dB, resulting in a sensitivity of *F*/9.6 and returning noise levels 6dB lower (around -50dB).

2.5 Shuttering

The camera has 3 CMOS sensors, and thus can be expected to exhibit the effects of a rolling shutter. A motion sequence was recorded, of a white card being moved vigorously back and forth in front of a focus chart. Figure 10 shows two fields from that sequence, which clearly show the expected 'leaning verticals' brought about through the rolling shutter (since the top of the field or frame is exposed significantly before the bottom of the field or frame). For this test, the camera was set to interlace mode, underexposed, and the shutter effectively turned off (i.e. 1/50 second). Had the shutter been set to a shorter period, the edge blurring would have been much less, but the slope would have remained.

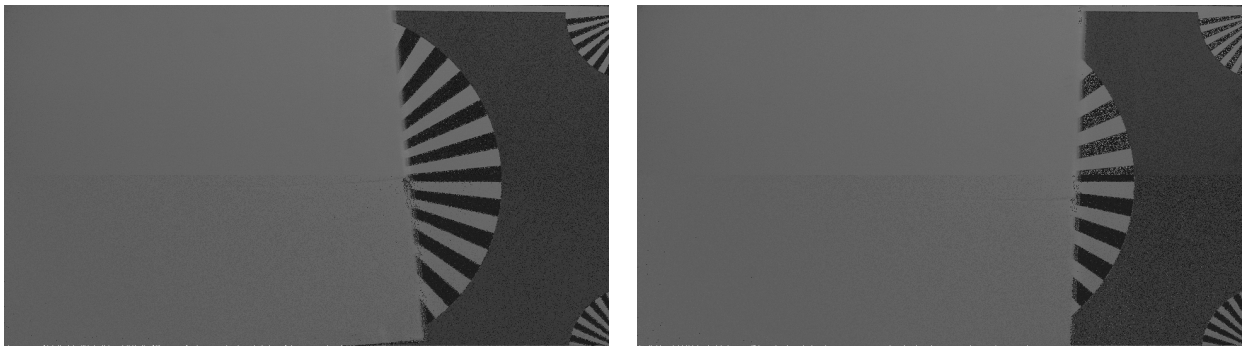


Figure 10, rolling shutter effect, (a) left to right motion (b) right to left motion

More spectacularly, the effect of the rolling shutter can be demonstrated by a rotating fan. Figure 11 shows images recorded of a small fan, two bladed, with symmetrical blades. The camera was et to a short shutter (about 1/1000, not critical) and the fan speed was adjusted to one of several critical speeds at which a stroboscopic effect was observed. The blades are compressed when on the left (going up, against the rolling shutter), grossly expanded on the right (going down, overtaking the rolling shutter).

Figure 11, rolling shutter effect, rotating fan, 1/1000 shutter

At one point, the right-hand blade in this sequence of adjacent recorded frames actually falls apart.

If the shutter is set to a more sensible speed (Figure 12), then the effect is far less visible, but the blurred blades still appear to be asymmetrical, being swept to the left. The combination of sloping verticals and distorted rotating elements may not often occur in programme-making, but the effects can be disturbing

when they accidentally occur. This camera is neither better nor worse than other cameras with CMOS sensors, the effects are an inevitable consequence of the use of rolling shutter in then camera.

Figure 12, rotating fan, 1/100 shutter

2.6 Conclusion

This camera performs well at HD, for such a small-image format. Resolution is very well maintained and is refreshingly alias-free. Detail controls work well, and the factory settings are good. Noise levels are typical for 1"/3 sensors, but sensitivity is unusually good. Operating the camera at significantly lower gain will reduce the noise level without sacrificing significant sensitivity.

The integral lens has a maximum aperture of *F*/1.6, unusually large for a small camera, and there was mo perceptible loss of resolution through iris diffraction until the lens was stopped down to F/8, at which point significant resolution was being lost. Again, this is unusual for such a small image size. Thus, the camera has a useful aperture range from *F*/1.6 to about *F*/6.8. This, together with the 3-stage neutral density filters (each providing a further 2-stops of control), means that the camera has a much better exposure control range than is normal in a small camera.

Performance at 720, while acceptable, is not ideal, since it appears to have been derived from the 1920x1080 signals, rather than by direct interpolation from the sensors. 720p performance can be improved significantly with the use of the noise reducer, but for best quality delivered pictures at 720, it is probably best to shoot and record at 1920x1080, and then to down-co0nvert as a post-production operation.