

Colorimetric and Resolution requirements of cameras

Alan Roberts

Addendum 65 : Tests and settings on a Canon XF100/105E

Tests were made on a Canon XF105E, serial number 293109900023, believed to be a pre-production model, and a confirmatory check on a production model (serial number 293220000068). There appears to have been no change between the two cameras under test.

The camera has a single $\frac{1}{3}$ " CMOS sensor, presumably with Bayer-pattern, and an integral lens. It records MPEG2-compressed video; all the tests were made by recording in the camera, since this is the most likely mode for the camera's use.

The XF100 and 105 are clearly lower-cost companions to the XF300 and 305, sharing many features between them. Sadly, the fold-out LCD panel on the 100/105 has been moved to the left-hand side of the camera from its much better position under the handle on the 300/305, where it can be swung out to either side of the camera. Also, there are only 10 user programmable buttons instead of the 13 on the bigger cameras, but 10 ought to be enough.

The 105 model has HDSDI output and can be genlocked, and has time-code connection, while the 100 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. These tests were made only on an 'E' (50Hz, PAL) model, but it's menus contain, under 'Other Functions' an item to select 'PAL/NTSC', so presumably this camera had been modified to be universal. All the tests were made in the 'PAL' mode, but the changes to the menus when switched into 'NTSC' mode have not been recorded here. 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 1.07kg. The built-in lens has 10:1 zoom range from 4.25mm to 42.5mm focal length (equivalent to 30.4 to 304mm in a full-frame 35mm camera), F/1.8-F/2.8. The sensor is CMOS, full-resolution 1920x1080, but with a Bayer pattern of colour filters, so full 1080-line resolution is not possible. 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 50fps is possible.

There is a conventional viewfinder (approximately 720x405 pixels), plus a separate LCD screen (approximately 1280x720 pixels) conventionally hinged on the left-hand 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 not exceptional, and is specified in an obscure way. On-screen video level monitoring is good, there are options for waveform monitoring on the LCD panel. There is also an image magnifier as a focus aid.

Connectivity is good, with HDSDI and timecode (only in the 105 model), plus HDMI and USB, analogue component, BNC analogue video, 3.5mm multifunction jack socket and XLRs for audio. Power consumption is about 6.2 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. 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 (Custom Files). There is no direct way to access these from the camera, they are accessed using the Menu button on the LCD panel. Control is simple, with a single joystick/button on the LCD panel.

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 for the E (PAL) model, 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
<i>Edit file</i>				
Rename	text			
Protect	<u>Unprotect</u> , Protect			
Reset	<u>Cancel</u> , OK			
Gamma	<u>Normal1</u> , Normal2, Normal3, Normal4, Cine1, Cine2	²	Normal 3	Cine1
<i>Black</i>				
Master Pedestal	-50~ <u>0</u> ~+50			
Master Black				
Red	-50~ <u>0</u> ~+50			
Green	-50~ <u>0</u> ~+50			
Blue	-50~ <u>0</u> ~+50			
<i>Black Gamma</i> ³				
Level	-50~ <u>0</u> ~+50	+ expands, - compresses	0	
Range	-5~ <u>0</u> ~+50		0	
Point	-1~ <u>0</u> ~+50		0	
<i>Low Key Satur</i>				
Enable	<u>On</u> , Off			Off ⁴
Level	-50~ <u>0</u> ~+50			
<i>Knee</i>				
Enable	<u>On</u> , Off	Highlight compression, not available in Cine gammas	On	
Automatic	<u>On</u> , Off		Off	
Slope	-35~ <u>0</u> ~+50		12 ⁵	
Point	50~ <u>95</u> ~109	Lovely, IRE values!	85	
Saturation	-10~ <u>0</u> ~+10	Preserve colour in highlights	0	
<i>Sharpness</i>				
Level	-10~ <u>0</u> ~+50		-5	-10
H Detail Freq	-8~ <u>0</u> ~+8			+8
<i>Coring</i>				
Level	-30~ <u>0</u> ~+50	To avoid sharpening noise		+12
D-Ofst	<u>0</u> ~50			
D-Curve	<u>0</u> ~8			
D-Depth	-4~ <u>0</u> ~+4			
HV Detail Bal	-8~ <u>0</u> ~+8		+2	+5
Limit	-50~ <u>0</u> ~+50			0
<i>Knee Aperture</i>				
Gain	<u>0</u> ~9		⁶	
Slope	0, <u>1</u> ~3		1	
<i>Level Depend</i>				
Level	<u>0</u> ~50	Prevent sharpening near black	⁷	
Slope	<u>0</u> ~3			

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-look for video, Cine 2=for transfer to film or for more saturated colours.

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 This setting gives about 1 stop of headroom, but Cine 1 gamma curve is better for a film look.

⁶ Use Knee Aperture gain in conjunction with Knee Slope; as Knee Slope goes down, Aperture Gain can go up, to maintain sharpness.

⁷ Use Level Depend in conjunction with Black Stretch, to prevent over-sharpening near black.

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>	
Offset	0~50			
Ingredient Ratio	-50~0~+50			
Noise Reduction	1~8, Off, <u>Automatic</u>		Automatic ⁸	
<i>Skin Detail</i>				
Effect Level	High, Middle, Low, <u>Off</u>	Soften skin tones		
Hue	-16~0~+16			
Chroma	0~ <u>16</u> ~31			
Area	0~ <u>16</u> ~31			
Y Level	0~ <u>16</u> ~31			
<i>Selective NR</i>				
Effective Level	High, Middle, Low, <u>Off</u>	Fine tune noise reduction ⁹		
Hue	-16~0~+16			
Chroma	0~ <u>16</u> ~31			
Area	0~ <u>16</u> ~31			
Y Level	0~ <u>16</u> ~31			
<i>Color Matrix</i>				
Select	<u>Normal1</u> , Normal2, Normal3, Normal4, Cine1, Cine2	Preset matrices ¹⁰	Normal 3	Cine 1
Gain	-50~0~+50			
Phase	-18~0~+18			
R-G	-50~0~+50		-8 ¹¹	
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			
<i>White Bal</i>				
R Gain	-50~0~+50			
G Gain	-50~0~+50			
B Bain	-50~0~+50			
<i>Color Correction</i>				
Select	<u>Off</u> , Area A, Area B, Area A&B	Tweak two colours	Off	
<i>Area A Setting</i>				
Phase	0~31			
Chroma	0~ <u>16</u> ~31			
Area	0~ <u>16</u> ~31			
Y Level	0~ <u>16</u> ~31			
<i>Area A Revision</i>				
Level	-50~0~+50			
Phase	-50~0~+50			
<i>Area B Setting</i>				
Phase	0~ <u>16</u> ~31			
Chroma	0~ <u>16</u> ~31			
Area	0~ <u>16</u> ~31			
Y Level	0~ <u>16</u> ~31			
<i>Area B Revision</i>				
Level	-50~0~+50			
Phase	-50~0~+50			
<i>Other Functions</i>				
<i>Setup Level</i>				
Level	-50~0~+50	Scales Black and Master Ped		
Press	On, <u>Off</u>	Squeezes video to 100%	Off ¹²	

⁸ 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 for 720 shooting, Auto is fine for 1080.

⁹ Selective Noise Reduction could be useful but will take significant time to set up to be effective.

¹⁰ 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.

¹¹ Matrix, see measurements section below.

¹² Press, not tested. This could be handy for shoot-and-run operations where exposure control is difficult.

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
Clip 100% IRE	On, <u>Off</u>	Clips hard at 100%	Off

CAMERA SETUP

Main video standard setting

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
Light Metering	Backlight, <u>Standard</u> , Spotlight	Auto exposure compensation	
AE Shift	+2, +1.5, +1.25, +1, +0.75, +0.5, +0.25, <u>0</u> , -0.25, -0.5, -0.75, -1, -1.25, -1.5, -2	Deviation from auto-exposure, stops	
AGC Limit	<u>Off/24</u> , 21, 18, 15, 12, 9, 6, 3dB	Max gain AGC will go to	
<i>Gain</i>			
L	Fine tuning, 33, 24, 18, 12, 6, 3, 0, -3, -6dB		-6dB
M	Fine tuning, 33, 24, 18, 12, <u>6</u> , 3, 0, -3, -6dB		-3dB
H	Fine tuning, 33, 24, 18, <u>12</u> , 6, 3, 0, -3, -6dB		6dB
Shutter	<u>Automatic</u> , Speed, Angle, Clear Scan, Slow		
Off	50i	1/50	BEWARE, 1/25 makes blurred motion
	25p	1/25	
Auto	50i	1/50~1/500	Not available in slow/fast motion shooting
	25p	1/25 ~1/500	
Angle	360, 300, 240, 180, 150, 120, 90, 60, 45, 30, 22.5, 15, 11.25	Degrees	
Clear Scan	50i	50~249.46Hz	
	25p	25 ~249.46Hz	
Slow Shutter	50i	1/3, 1/6, 1/12, 1/15	Not available in slow/fast motion shooting
	25p	1/3, 1/6, 1/12	
Infrared Mode	50i	1/50~1/120	
	25p	1/25~1/120	
Slow Shutter in IR mode	50i	1/25~1/120	
	25p	1/12~1/120	
ND Filter	<u>Automatic</u> , Off	No manual control over ND filters	
White Balance	<u>Daylight</u> , Tungsten, Kelvin	Kelvin sets colour temp. directly	
<i>AF Mode</i>			
Speed	<u>Instant</u> , Medium, Normal	Manually tweaking the focus ring overrides auto mode	
Face AF	Face Pri, Face Only, <u>Off</u>	Auto focus on a face	
Focus Limit	On, <u>Off</u>	On=1m, Off=2cm (macro)	
OIS Function	Axis Shift ¹⁴ , <u>Img Stab.</u> , Off	Degree of stabilisation, powered for tripod use, dynamic for walking, standard is lowest.	
<i>Axis Shift</i>			
Reset	Cancel, Ok		
Adjust	-		
GUI Color	<u>Yellow</u> , Green		
Image Stabiliser	Dynamic, <u>Standard</u>		
<i>Zoom</i>			
Speed Level	Fast, <u>Normal</u> , Slow		
Soft Zoom Control	Both, Stop, Start, <u>Off</u>		
<i>Grip Rocker</i>	Constant, <u>Variable</u>	Variable is pressure sensitive	
Constant Speed	1~8~16		
Handle Rocker	Off, 1~8~ <u>16</u>		
Wireless Controller	1~8~16		
Focal Length Guide	Set To 0, <u>Off</u>		
Teleconverter	6x, 3x, 1.5x, <u>Off</u>		
Flicker Reduction	Automatic, <u>Off</u>	Compensate for lighting flicker	
Conversion Lens	TL-H58, WD-H58W, <u>Off</u>	Compensate TL (tele) or WD (wide)	

¹³ **BEWARE, 25p defaults to 1/25, use Angle setting to get 180°.**

¹⁴ Axis shift uses the internal motors to steer the optical axis, ideal for setting convergence when used in 3-D shooting.

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Color Bars</i>			
Enable	On, <u>Off</u>		
Type	<u>Type 1</u> , Type 2	EBU, SMPTE	Type 2
<i>Infra Red</i>			
Monochrome	<u>White</u> , Green		
Light	<u>Toggle</u> , Always On, Always Off	Toggle switches via Custom button	
Slow Shutter	On, <u>Off</u>		
<i>Custom Picture</i>			
CP Select File			
CP Edit File			
CP Transfer File			

AUDIO SETUP

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Audio Input</i>			
XLR Rec Channel	<u>CH1</u> , CH1/2		
Int Mic Low Cut	<u>Off</u> , LC1, LC2	1 for voices, 2 for wind cut	
Int Mic Sensitivity	<u>Normal</u> , High	High=+6dB	
Int Mic Att	On, <u>Off</u>	On=-12dB	
XLR1 Mic Trim	+12, +6, <u>0</u> , -6, -12dB		
XLR2 Mic Trim	+12, +6, <u>0</u> , -6, -12dB		
XLR1 Mic Att	On, <u>Off</u>		
XLR2 Mic Att	On, <u>Off</u>		
XLR ALC Link	Linked, <u>Separate</u>	Use link for stereo recording	
Limiter	On, <u>Off</u>	Limit at -4dB ¹⁵	
1kHz Tone	-12, -18, -20dB, <u>Off</u>	Tone over colour bars	
<i>Audio Output</i>			
Monitor Delay	Line out, <u>Normal</u>	Set headphone sound delay	
Channel	<u>CH1/2</u> , CH1/1, CH2/2, All/All	All does mono mix	
Level	1V rms, 2Vrms	1V=0dB, 2V=+6dB	
Headphone Volume	Off, 1~8~15		
Speaker Volume	Off, 1~8~15		

VIDEO SETUP

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
SDI Output	HD, SD, <u>Off</u>	XF105 only, Off saves battery power	
Component Output	<u>HD</u> , SD		
HD Onscreen Disp	On, <u>Off</u>	Puts camera screen messages on output, not on recording	
SD Onscreen Disp	On, <u>Off</u>		
SD Output	<u>Squeeze</u> , Letterbox, Side crop		

LCD/VF SETUP

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>LCD Setup</i>			
Brightness	-99~ <u>0</u> ~+99		
Contrast	-99~ <u>0</u> ~+99		
Color	-20~ <u>0</u> ~+20		
Sharpness	1, <u>2</u> , 3, 4		
Backlight	<u>Normal</u> , Bright		
<i>VF Setup</i>			
Brightness	-99~ <u>0</u> ~+99		
Contrast	-99~ <u>0</u> ~+99		
Color	-3~ <u>0</u> ~+3		
Backlight	<u>Normal</u> , Bright		
Backlight	<u>Normal</u> , Bright		
LCD/VF B&W	On, <u>Off</u>	On=mono	
LCD/VF Simul	On, <u>Off</u>	On=v/f and LCD on together	

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

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Metadata Display</i>			
Date/Time	On, <u>Off</u>	Only in playback mode	
Camera Data	On, <u>Off</u>		
<i>Peaking</i>			
Select	<u>Peaking 1</u> , Peaking 2	Two settable peaking regimes	
<i>Peaking 1</i>			
Color	<u>White</u> , Red, Yellow, Blue		
Gain	Off, 1~8~15		
Frequency	1, <u>2</u> , 3, 4		
<i>Peaking 2</i>			
Color	White, <u>Red</u> , Yellow, Blue		
Gain	Off, 1~ <u>15</u>		
Frequency	<u>1</u> , 2, 3, 4		
<i>Zebra</i>			
Select	<u>Zebra 1</u> , Zebra 2, Zebra 1&2		
Zebra 1 Level	<u>70</u> , 75, 80, 85, 90, 95%	Active over $\pm 5\%$ of target	70
Zebra 2 Level	70, 75, 80, 85, 90, 94, <u>100%</u>	Active above target level ¹⁶	100
HD Output	On, <u>Off</u>	Show zebras on HD outputs	
<i>Markers</i>			
Enable	On, <u>Off</u>		
Center	White, Gray, <u>Off</u>		
Horizontal	White, Gray, <u>Off</u>		
Grid	White, Gray, <u>Off</u>		
Safety Zone	White, Gray, <u>Off</u>		
Safety Zone Area	80, 90, 92.5, <u>95%</u>		
Aspect Marker	White, Gray, <u>Off</u>		
Aspect Ratio	4:3, 13:9, 14:9, 1.66:1, 1.75:1, 1.85:1, <u>2.35:1</u>		14:9 ¹⁷
<i>Audio Level</i>	<u>On</u> , Off		
<i>Custom Display 1</i>			
Zoom Position	Always on, <u>Normal</u> , Off	Normal=only when changing	
Light Metering	<u>On</u> , Off		
Custom Picture	<u>On</u> , Off		
ND Filter	<u>On</u> , Off	Normal=only when changing	
Focus Mode	<u>On</u> , Off		
Object Distance	Warning, <u>Normal</u> , Off	Normal=only when focusing	
Full Auto/Lock	<u>On</u> , Off		
Infrared	<u>On</u> , Off		
White Balance	<u>On</u> , Off		
Exposure	<u>On</u> , Off		
Iris	<u>On</u> , Off		
Gain	<u>On</u> , Off		
Shutter	<u>On</u> , Off		
Conversion Lens	<u>On</u> , Off		
Teleconverter	<u>On</u> , Off		
Peaking	<u>On</u> , Off		
Magnification	<u>On</u> , Off		
OIS	<u>On</u> , Off		
<i>Custom Display 2</i>			
Remaining Battery	Warning, <u>Normal</u> , Off		
Remaining Rec Time	Warning, <u>Normal</u> , Off		
Rec Mode	<u>On</u> , Off		
Genlock	<u>On</u> , Off		
Time Code	<u>On</u> , Off		
Interval Counter	<u>On</u> , Off		
SD Card Status	Warning, <u>Normal</u> , 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.

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
Bit Rate/Resolution	<u>On</u> , Off		
Frame Rate	<u>On</u> , Off		
Character Rec	<u>On</u> , Off		
Wireless Controller	<u>On</u> , Off		
Output Display	On, <u>Off</u>		
SDI Rec Command	<u>On</u> , Off		
User Memo	<u>On</u> , Off		
User Bit	<u>On</u> , Off		
Audio Output Ch	<u>On</u> , Off		
Date/Time	Date, Time, Date/Time, <u>Off</u>		

TC/UB SETUP

Time-code and User Bits

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Timecode</i>			
Mode	<u>Preset</u> , Regen		
Run	<u>Rec run</u> , Free run		
Setting	<u>Set</u> , Reset	Opens menu to set TC and UB	
<i>User bits</i>			
Rec Mode	<u>Internal</u> , External	Not available on XF100 models	
Type	<u>Setting</u> , Time, Date		

OTHER FUNCTIONS

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Reset</i>			
All Settings	<u>Cancel</u> , OK		
Camera Settings	<u>Cancel</u> , OK		
Assignable Buttons	<u>Cancel</u> , OK		
<i>Transfer Menu</i>			
Save To	<u>Cancel</u> , OK		
Load From	<u>Cancel</u> , OK		
Time Zone	-12.00~+1.00~+14.00		
<i>Clock Set</i>			
Date/Time	-		
Date Format	YMD, YMD/24H, MDY, MDY/24H, <u>DMY</u> , DMY/24H		
<i>WFM (LCD)</i>			
Setting	WFM, Edge mon, <u>Off</u>		
Setting	WFM, <u>Off</u>		
<i>Waveform Monitor</i>	<u>Line</u> , Line+spot, Field, RGB, YPbPr	Spot adds waveform for the screen area in the red frame	
Gain	<u>1x</u> , 2x	+6dB gain	
Edge Mon	<u>Type 1</u> , Type 2		
Language	German, <u>English</u> , Spanish, French, Italian, Polish, Russian, Simplified Chinese, Japanese	Language for screen messages. Menus/settings remain in English	
Wireless Controller	<u>On</u> , Off	Remote control	
Assign Button	None, Img Stab, Powered S, Focus Limit, Face AF, Select Face, Backlight, Spotlight, Teleconverter, Peaking, Zebra, WFM (LCD), Magnification, TL- H58, WD-H58W, Color bars, IR Monochrome, IR Light, Markers, 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, Delete last clip, Status	10 assignables, marked: 1=Powewred IS 2=Zebra 3=WFM LCD 4=Magnification 5~10 None	
<i>Custom Key/Dial</i>			
Normal	<u>Iris ND</u> , Face AF, Headphone Volume, Teleconverter, Off		
Infrared	<u>IR Light</u> , Headphone Volume, Teleconverter, Off		

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
<i>Tally Lamp</i>			
Front	<u>On</u> , Off		
Rear	<u>On</u> , Off		
Media Access LED	<u>On</u> , Off		
Genlock	<u>Gen/TC in</u> , TC out	XF105 only	
Genlock Adjust	-1023~0000~+1023	Horizontal phase, XF105 only	
Relay Rec	<u>On</u> , Off		
Double Slot Rec	<u>On</u> , <u>Off</u>		
Bit Rate/Resolution	<u>50Mb/s 1920x1080</u> , 50Mb/s 1280x720, 35Mb/s 1920x1080, 35Mb/s 1280x720, 25Mb/s 1440x1080		50Mb/s 1920x1080 ¹⁸
Frame Rate	<u>50i</u> , 50p, 25p		¹⁹
Special Rec	Interval rec, Frame rec, Pre rec, Slow & fast motion, <u>Off</u>	Non-standard shooting	
<i>Interval Rec</i>			
Interval	<u>1</u> ~10, 15, 20, 30, 40, 50 sec, 1~10 min		
Rec Frames	<u>2</u> , 6, 12		
Frame Rec Rec Frames	<u>2</u> , 6, 12		
<i>Slow & Fast Motion</i>			
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
	25Mb/s	12, 15, 18, 20, 21, 22, 24, 25, 26, 27, 28, 30	
<i>Clips</i>			
Title Prefix	<u>AA</u> ~ <u>ZZ</u>	Text entry	
Number Setting	<u>Set</u> , Reset		
Delete Last Clip	<u>Cancel</u> , OK		
Copy All Clips	<u>Cancel</u> , OK	Copy clips card to card	
Copy OK Clips	<u>Cancel</u> , OK	Copy only OK-marked clips	
Delete All Clips	<u>Cancel</u> , OK	Delete all except OK-marked	
Delete All OK Marks	<u>Cancel</u> , OK	Un-mark all clips	
Rec Review	<u>Entire clip</u> , last 4 sec	Play last 4 seconds of last clip	
<i>Set Metadata</i>			
User Memo	<u>Off</u> , 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		
SDI Rec Command	<u>On</u> , <u>Off</u>	Only on XF105	
Photo Numbering	Reset, <u>Continu</u>		
<i>Add CP File</i>			
To Clip	<u>On</u> , Off	Copies settings to clip or photo as metadata	
To Photo	<u>On</u> , Off		
Delete All Photos	OK, Cancel	Wipes the SD card	
<i>Custom Function</i>			
Shockless Gain	Fast, Normal, Slow, <u>Off</u>	Auto gain control	
Shockless WB	<u>On</u> , <u>Off</u>	Auto white tracking	
AE Response	Fast, <u>Normal</u> , Slow		
Iris Limit	<u>On</u> , <u>Off</u>		
I. Ring Direction	Reverse, <u>Normal</u>		
F. Ring Direction	Reverse, <u>Normal</u>		
Z. Ring Direction	Reverse, <u>Normal</u>		
F. Ring Control	Fast, <u>Normal</u> , Slow		
Z. Ring Control	Fast, <u>Normal</u> , Slow		
F. Assist B&W	Both, Magnify, Peaking, <u>Off</u>		
Obj. Dist Unit	Meters, <u>Feet</u>		
Zoom Indicator	<u>Bar</u> , Number		
ZR-2000 AE Shift	<u>AE shift</u> , Iris		

¹⁸ This is the minimum coding specification accepted for EBU broadcasting at the time of writing (December 2010).

¹⁹ 50i and 25p are available in 1080-line modes, 50p and 25p in 720p mode. **BEWARE, the default shutter in 25p is 1/25 second which delivers blurred motion, set it to 1/50 (180°) for use at 25p.**

<i>Item</i>	<i>Range</i>	<i>description</i>	<i>Pref</i>
Scan Reverse Rec	Both, Vertical, Horizontal, <u>Off</u>		
Character Rec	On, <u>Off</u>		
Reset Hour Meter	<u>Cancel</u> , OK		
<i>Initialization</i>			
CF A	<u>Cancel</u> , OK	Format card	
CF B	<u>Cancel</u> , OK		
SD Card	Complete, Quick		
Firmware		Shows firmware versions	

2 Measurement results

All measurements were made by recording images at the highest data rate, 50Mb/s, then importing the captured files into Canopus Edius, and exporting still frames as bitmap files for analysis in specialist software.

2.1 Colour performance

Assessments were made visually, using Macbeth charts as usual. Performance was generally good, but the skin-tone colours were a little pink. Using the matrix, it should be possible to effect some improvement, by lowering the R-G value a little, and there may have been more improvements to be gained by spending more time on this assessment, and possibly using the colour corrector. However, the results from the brief test session 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, an NHK curve, but Gamma 3 is the ITU-709 curve and Gamma 4 the BBC 0.4 curve, both of which produce better colour rendering. 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 and delivers slightly lower noise levels, 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, Cine1 is less saturated than Cine2, but both are acceptable for film-look. In each case, the matrix was changed to match the gamma selected, and the results appear to be consistent and appropriate.

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, 1080-line

Although the camera can be set to either 50i or 25p in 1920x1080 mode, there was no visible difference in resolution between these modes. However, with the shutter setting set to ‘Off’ in 25p mode, the shutter duration defaults to 1/25, which results in a ‘free’ stop of signal gain but very blurred motion.

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 strong diagonal aliases, and coloured horizontal and vertical aliases, which is a clear indication that the sensor has a Bayer-pattern structure. Also, the fact that the coloured aliases are centred on the extremes of the pattern proves that the sensor is 1920x1080, confirming the specification in the manual.



Figure 1 Zone Plate, 25p

In a camera with a single Bayer-patterned sensor, the red and blue patterns each have half vertical and horizontal resolution, because the pattern of pixels alternates between ...RGRGRGRG... and ...GBGBGBGB... line by line, thus red pixels appear in alternate columns and lines as do blue pixels. Therefore the clean resolution limits for red and blue are half that of the sensor. The green pixels form a quincunx array (Domino-5 pattern), which is best understood as an array of diagonal lines rather than horizontal and vertical. Thus, the green resolution is rotated by 45°, and therefore reduced by $1/\sqrt{2}$. This results in the green resolution achieving full horizontal resolution when there is no vertical resolution, and full vertical resolution when there is no horizontal resolution, a diamond shape rather than square with the diagonals reaching the sensor's horizontal and vertical extremes. The diamond nature of this resolution is clearly visible in Figure 1, where the demarcation between wanted and aliased resolution is a diagonal line from the horizontal extreme to the vertical. The coloured aliases around 1920 horizontal and 1080 vertical are due to the reduced nature of the red and blue resolutions.

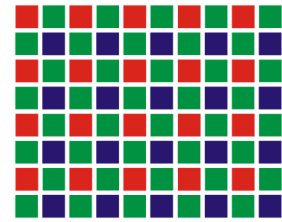


Figure 2 Bayer pattern

The only way to get good resolution from a Bayer-patterned sensor is to have more pixels, typically 2880x1620 would be enough to deliver full resolution at 1920x1080.

2.3.2 Resolution, 720p

The internal down-conversion to 1280x720 performs as expected, frequencies outside the resolution limits of 1280x720 are aliased in the image. Better down-conversion is possible using a separate conversion process, either in software or hardware. However, the noise reduction filtering can be used as an alternative, as will be shown later.

2.4 Video Noise Levels

Video noise was measured by recording a white card, uniformly lit, and performing numerical analysis in software. The camera was set to 0dB gain, there was no need to use a higher gain setting. A software high-pass filter was used to remove all horizontal frequencies below about 5% of the nominal maximum of half-sampling frequency, thus eliminating the effects of any lighting shading.

Initially, noise reduction was turned off, and the results are shown in Figure 3. The distribution of noise levels does not follow the expected curve, of increasing noise level as the video signal level falls. If the sole noise-source is the sensor itself, the noise level at 10% video should be about 10dB higher than at 90%. The effectively flat distribution shown here could have several causes, but the simplest seems the most likely, that gamma correction is done in the analogue-signal domain, using amplifiers with limited gain-bandwidth product. Thus, as the gain is increased towards black, the bandwidth falls and noise level is contained. A possible alternative is that there is some form of noise reduction taking place, even though the menu-controlled noise reduction was switched off. Either way, the lower levels of noise near black give the impression of a low-noise picture, despite there being significant noise near white. The achieved figure of about -45.5dB (for luma at mid-grey) is reasonable, but indicates that using high levels of camera gain is not a good idea.

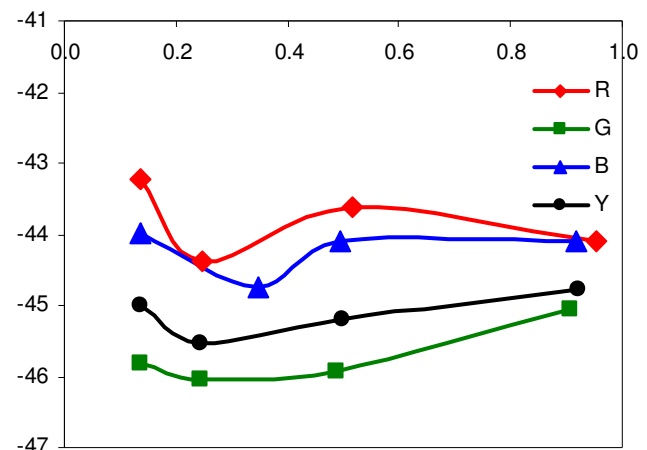


Figure 3 Noise levels, 1080p, NR off

There is a noise advantage of about 1.8dB to be gained from using the noise reduction in Automatic mode. There was little or no discernable loss of resolution as a result of noise reduction, and so this noise reduction is worth having. However, in manual mode, there is quite dramatic loss of resolution at high noise-reduction levels.

Figure 4 shows the effect of setting noise reduction to level 5 when shooting in 1280x720p mode. The diagonal aliases are almost totally suppressed, while the horizontal and vertical coloured aliases are only just visible. Clearly, the spatial-filtering performed by the noise-reduction process is exactly what is needed as a pre-filter for the internal down-conversion. Not only that, but the noise levels are reduced by about 6dB, to -51dB as well. Therefore, for shooting at 1280x720, it is strongly advisable to set noise reduction to level 5. This setting is also recommended when shooting either at 1920x1080 or 1280x720 when intending to use the output signal for an SD production via an external down-converter, but the loss of resolution inevitably means that the recorded pictures cannot be used for different resolution systems (i.e. the pictures at NR 5 are too soft for 1080 use).

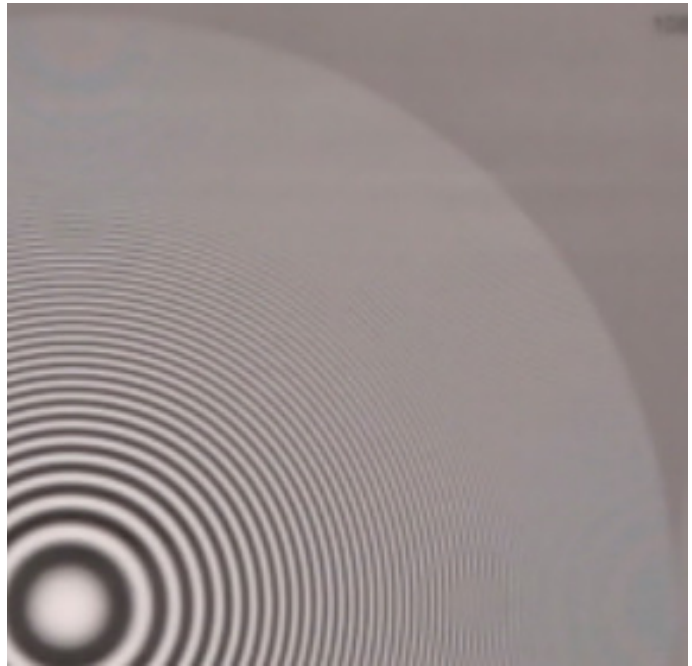


Figure 4 Zone Plate 1280x720, NR 5

2.5 Video Sensitivity

Sensitivity was measured directly. The card was exposed to a blank white card, illuminated at 1620lux (the maximum achievable under the test conditions). The camera was set to 25p, with a conventional gamma curve (gamma 3) and the aperture adjusted to achieve 100% video level. There is no direct access to the lens controls, only indicators in the viewfinder, so some interpolation was needed to get a measure of the aperture. The indicator showed F/4.0, but the control was near to changing to F/4.4. Applying a corrector for the illumination level ($2000/1620=1.235$) would return a definite value of F/4.4 for 2000 lux. However, the default shutter setting for 25p is 1/25 second, and not the usual 1/50 (180°), so an extra stop has been gained, which would not normally be used when shooting 25p. Applying corrections for this, we get a sensitivity figure of about F/3.2, which is about the right value for a 1920x1080 single silicon sensor.

The camera's specification claims minimum illumination to be 0.08 lux at 50i, with +33dB gain and 1/2 second shutter, and the lens, presumably, wide open (F/1.8). Compensating for the long shutter gives a light-level factor of $50/3=16.7$, resulting in 1.33 lux at 1/50. Compensating for the video gain gives another factor of $10^{33/20}=44.67$, resulting in 59.56 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 $F/1.8*\sqrt{(2000/59.96)}=F/10.4$. So, the specified sensitivity, expressed in conventional terms is F/10.4 at 2000 lux with standard gain and shutter.

Clearly, both values cannot be right. The specification must be referring to the minimum illumination level at which pictures are usable, and not to the achievement of peak white. The measured figure differs from the specified figure by 3.5 stops, which implies that the specified sensitivity would return a video signal of about 50% amplitude at that illumination level.

2.6 Shuttering

The camera has a CMOS sensor, and thus can be expected to exhibit the effects of a rolling shutter. This is easily demonstrated by using a rotating fan.

Figure 5 shows one frame of a small fan, two bladed, with symmetrical blades. The camera was set to a short shutter (about 1/300, 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).

If the shutter is set to a more sensible speed 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, partial-exposure from incidental flash-photography and distorted rotating elements may not often occur in programme-making, but the effects can be disturbing when they accidentally happen. 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 the camera.



Figure 5 Rotating fan, 1/3000 exposure

2.7 Infrared response (IR)

Small cameras are usually sensitive to Infrared. The sensor material (silicon) is highly sensitive to IR, and so it is customary for high-end cameras to have optical filters which prevent IR from reaching the sensors. But optical parts are expensive, and so cheaper cameras often have no such filter or an inadequate one. The same is true for the spatial low-pass filter which is common in broadcast cameras, but often not so in consumer cameras (this filter prevents the worst of spatial aliasing).

It is a simple matter to test for IR response in a camera, point a consumer-electronics remote-control into the lens, and press a button. If the camera shows the LED flashing, then the camera is responding to IR radiation at about 933nm wavelength, which is invisible to the human eye. Such response pollutes black levels and produces odd effects from some fabrics under some illuminants, making colour performance unpredictable.

On test, the XF105 did show some response to IR, but not excessively so. However, the camera has a switch under the lens, marked 'Infrared, On/Off'. Setting this switch to 'On' removes the internal IR filter and results in a significant increase in apparent sensitivity, but all manual exposure control is lost since the camera goes into a fully automatic mode. This may be a problem for professional and broadcast applications, where manual control is always expected. There is also an IR 'light' mounted in the lens assembly. Figure 6 shows the spatial response of the camera in IR mode.

Figure 6 shows the spatial response of the camera in IR mode. It consists of two side-by-side images of a zone plate. The left image (a) shows the response with the IR filter (NR) turned off, and the right image (b) shows the response with the IR filter (NR) turned on. Both images show a circular pattern of concentric rings, but the right image (b) shows a more pronounced and regular pattern, indicating a significant increase in sensitivity to IR radiation when the filter is removed.

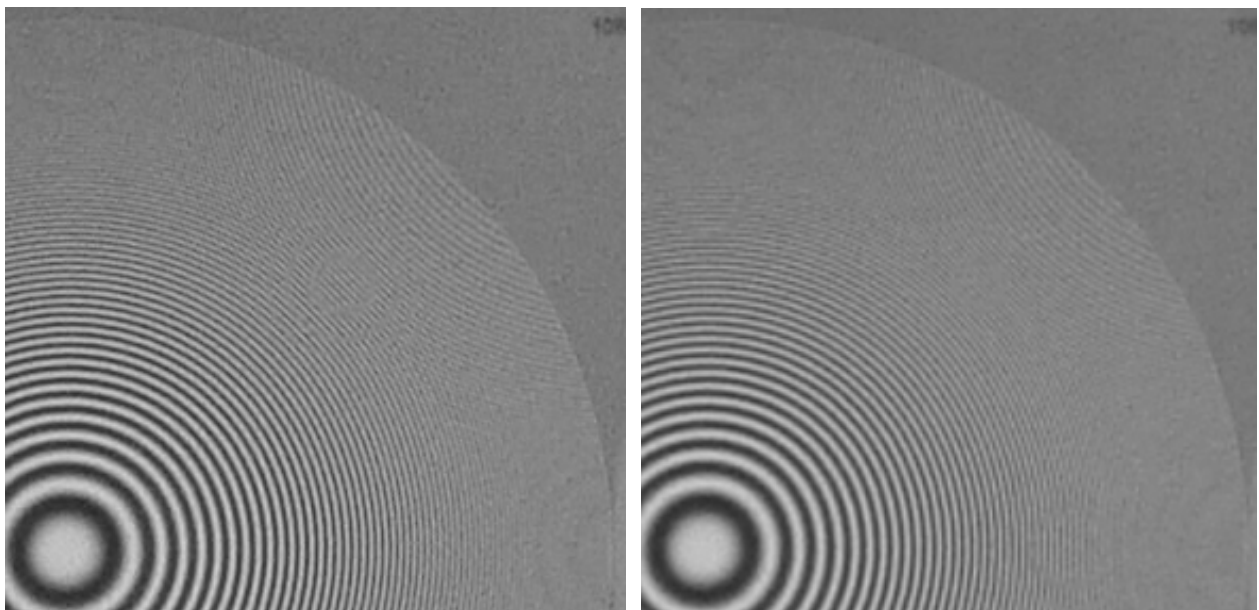


Figure 6 Zone Plate, IR, a) NR off

b) NR 5

The response is fairly noisy, and the resolution is somewhat reduced. Spatial aliasing is still clearly visible, particularly diagonally. However, setting the noise reduction to level 5 reduces the noise level significantly, and helpfully lowers the level of spatial aliasing. If the camera is to be used in IR mode, then setting it to 1280x720 makes most sense, and the noise reduction can be set to at least 5, possibly a little higher.

2.8 Conclusion

This camera performs reasonably well at HD, for such a small-image format with a single sensor. Resolution is maintained up to 1280x720, but contains inevitable spatial aliases due to the use of a Bayer-patterned sensor. Detail controls work reasonably well, but not as well as they would have done with 3 sensors. Noise levels are typical for a 1/3" single sensor, and sensitivity is as expected. Operating the camera at significantly lower gain will reduce the noise level without sacrificing significant sensitivity.

The integral lens has a maximum aperture of $F/1.8$, normal for a small camera, and there was no perceptible loss of resolution through iris diffraction until the lens was stopped down to $F/11$, at which point significant resolution was being lost (iris diffraction would normally be expected to start at about $F/5.6$, but the spatial aliases effectively disguise the effects of diffraction). Thus, the camera has a useful aperture range from $F/1.8$ to about $F/10$. This, together with the in-built neutral density filters (up to 3 stops), means that the camera has a good exposure control range.

Performance at 720p is acceptable, since it appears to have been derived directly from the sensor, rather than from 1920x1080 signals. 720p performance can be improved significantly with the use of the noise reducer, which also reduces video noise to a respectable level.