Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 34 rev1 : Assessment and settings for Sony HVR-Z5E and HVR-Z7E

Data for this addendum is taken from a short examination of production model of each of the Sony Z5 (serial number 00001, clearly an early model) and Z7 HDV (a retailed model) camcorders and from their manuals. The cameras are nearly identical, therefore it makes sense to report on them together.

They are HDTV camcorders, physically very similar to the Z1, with 3 ⅓" cmos sensors, but the Z7 has an interchangeable lens with a Sony proprietary lens mount while the Z5 has an integral Sony lens. The manuals claim that the sensors are approximately 1.12Megapixels, delivering resolution up to1440x810, with approximately 1,037Megapixels used for 16:9 capture. They both record HDTV using the HDV algorithm onto standard DV tapes (1080i and 1080psf) or Compact Flash solid-state cards, and SDTV using DVCAM or DV format. The similarity to the Z1 is only superficial.

The cameras are relatively light (about 2.8kg in including lens and battery) and have an integral viewfinder, with side lcd panel, and seem aimed at the high-end professional market rather than full broadcast, which would normally demand an image format larger than ⅓". The lens mount of the Z7 is specific to the ⅓"format, but adaptors are available to permit the use of ½" lenses. The Z7 was tested using the supplied Zeiss 12:1 zoom lens.

There are internal menus for setting the performance, not as complex as in a full broadcast camera, but enough to control some of the important features, albeit only in "on/off" states. They are not well suited to multi-camera operation since they cannot be remotely controlled. There are analogue-only video outputs (components and SD-composite via a multi-pin connector and S-video SD) and digits via IEEE1394 Firewire (known as i.Link by Sony) and 8-bit HDMI. A broadcast camera would normally be expected to have a 10-bit HDSDI output.

The same assessment procedure was used as for other HD cameras, partly attempting to get a good "film-look", and the settings reflect that. However, because of the lack of internal test signals, it was necessary to make more complex measurements than normal, through the lens. Since many camera parameters are undefined in the specifications, more measurements than usual were necessary. In the search for a "film-look" setting it is normal to think of the camera to be mimicking a film camera and telecine, with "best light" transfer to tape, with about 10 stops of tonal range. Assuming that a grading operation will be used in post-production, the settings attempt to give the colourist the same range of options as with film, but without achieving the full 10-stop dynamic range. The recommended settings allow about 1.7 stops of over-exposure and one of under-exposure relative to normal operation. This is not as good as can be achieved in ⅔" cameras, and arises from the difference in pixel size (the pixels here are much smaller, so sensitivity is maintained at the expense of highlight handling and video noise).

Colorimetric and Resolution requirements of cameras

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ADDENDUM 34 rev1 : Assessment and settings for Sony HVR-Z5E and Z7E

Data for this is taken from tests on production models of the Sony HDV camcorders, HVR-Z5E and Z7E. They are near-identical camcorders with three ⅓" cmos sensors (5.9mm diagonal, each approximately 1440x810 with precise half-pixel offset of green from red and blue). They record with HDV coding (1080i/25, 50Hz interlaced or progressive, and a proprietary 1080p/25 format) onto miniDV tapes, and standard definition (576i/25) as either miniDV or DVCAM. They can also record onto Compact Flash cards.

The cameras are essentially professional models, having some professional features such as having XLR connectors at mic or line level. The Z5 has an integral lens while the Z7 has interchangeable lenses, both have integral viewfinder and side-top lcd panel. Resolution is good enough for HDV, but vertical resolution could be better. Minimum exposure is claimed to be 1.5 lux.

There are many internal menus for setting the performance and a reasonable selection of external controls. There are analogue video outputs (components and composite plus S-video at SD, all via multi-pin connectors) and digits via IEEE1394 Firewire (known as "i.Link" by Sony) and HDMI. All measurements were made using the 8-bit HDMI output, converted to 10-bit HDSDI for image monitoring and capture.

The normal assessment procedure for full broadcast cameras could not be used, largely because the Z7 does not have a selectable test signal. Therefore, testing had to be done the hard way, via the lens. Recommended settings allowing for a "video-look" and a "film-look" have been derived, although there are some significant compromises that have to be taken into account.

It is useful to think of the camera, when used with "film-look", to be mimicking a film camera and telecine, with "best light" transfer to tape. Measurement results are given after the settings tables, in order to explain the decisions. At best, the camera can deliver about 10 stops of exposure range, similar to other HD cameras, but it is easy to set the camera such that exposure range drops to 7 stops or less. In the target market for this camera, a grading operation may well not be used in post-production, so the settings should be used with care.

The HDV performance is acceptable at sub-broadcast level for HDTV production, but is not up to the standards expected for full HDTV broadcast. There are a few problems with the picture performance as an SD camera for professional or broadcast purposes, although both cameras are better than the HVR-Z1 both in HD and SD modes. Performance with the recommended settings is probably adequate for consumer and semi-professional use, but better performance can be expected with a professional hardware or software down-converter. The reasons for this statement are given in the measurements section of this document.

The controls for these cameras are not as flexible as for full "broadcast" cameras, so more effort was expended in measuring performance than in trying to derive a specific "look" for it. Very small physical lens apertures (less than F/4) soften the picture and produce visible colour-fringing due to diffraction effects in the iris, the included neutral density filters are the better alternative to small apertures when shooting in very bright light.

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, the values indicate the range, and no scales are given. The numbers represent the count of bars in the thermometer presentation from the left, usually 1 to 16 with 8 being the central (default) value. Default settings, where known, are underlined. My recommendations are in the last column, labelled "BBC", where appropriate. Settings are given for:

v Television production
f Film-look television

In the tables, items that have an important effect on picture appearance are highlighted with grey background. Rather than just making assertions about performance, I have included measurement results that illustrate the reasons for recommending settings. Virtually all picture control is in the **Profile** menus.

Note that, in each power-switch mode, the menus can be separately customised, adding or removing any menu item from the entire set of menus.

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

1 Switches and Menu settings

The test session on the Z5 was very brief, and there was no manual available either on paper or as a download. The names and positions of controls here are for the Z7, but are expected top be accurate for the Z5 as well, but I cannot guarantee that. Also, menu items are taken from the Z7 manual; where the Z5 differs from the Z7, items are identified as such.

SWITCHES and BUTTONS

name	place	feature	comment
Zoom	Right	Rocker	
Expand focus	Right	Push	
Iris	Right	Switch	
Push Auto	Right	Push	
Rec Start/Stop	Right	Push	
ND filter	Left		
Assign 1 to 3	Left	Push	User buttons
Assign 4	Left	Push	Zebra/Assign 4
Assign 5	Left	Push	AE Shift/Assign 5
Assign 6	Left	Push	Rec Review/Assign 6
Gain	Left	Push	Manual control/indicator
Audio 1/2	Left	Switch/dial	Audio level controls
Auto/Manual	Left	Switch	
Shutter Speed	Left	Push	
White Balance	Left	Push	
Sel/Push Exec	Left	Dial	Menu controls
White balance stores	Left	Push	Cycles through white balances
White Balance	Left	Switch	
Gain	Left	Switch	
1394 connector	Back	Socket	
Analogue component	Back	Socket	Proprietary format mini-connector
A/V Out	Back	Socket	Another proprietary mini-connector
LANC	Back	Socket	Remote control
Headphones	Back	Socket	
Zoom	Handle	Rocker	
Zoom	Handle	Switch	Enables handle zoom rocker
Rec Start/Stop	Handle	Push	
Status Check	Left	Push	
Picture Profile	Left	Push	Most of the important camera controls
Menu	Left	Push	
Shot Transition/Focus Marking	Top	Push	Multi-function transition control
A	Top	Push	Condition A settings
B	Top	Push	Condition B settings
Zoom	Left	Switch	Auto/Manual
Digital Extender	Left	Push	Lens range extender, not a good idea
TC/U-Bit	Handle	Push	Toggles between timecode and user bits on lcd
Tape controls	Handle	Push	The usual tape controls
Volume/Memory	Handle	Push	Tape play volume, or select still to view
Memory/Delete	Handle	Push	For viewing stills
Memory/Index	Handle	Push	For viewing stills
Memory/Play	Handle	Push	For viewing stills
Reset	Handle	Push	Recessed, factory reset

CAMERA SET menu

Basic camera settings

item		range	comments	BBC
Iris/Exposure	Z5	Iris, Exposure	Allows direct control of iris	
Ring Rotate	Z5	Normal, Opposite		
Gain setup	Z5	-6, -3, 0, 3, 6, 9, 12, 15, 18, 21dB	Set gain for each position of the gain switch	
Gain setup	Z7	0, 3, 6, 9, 12, 15, 18, 21dB		
Smooth Gain		Fast, Middle, Slow, Off	Speed of gain change, Off=instant	
Hyper Gain		On, Off	On disables Backlight/Sptolight compensations	
AGC Limit	Z5	21dB, 18, 15, 12, 9, 6, 3, 0, -3, -6, Off	Upper limit for video auto gain	
Minus AGC	Z5	On, Off	Allow AGC to go to -6dB	
WB preset	Z5	Outdoor, Indoor, Manu WB Temp		
AGC Limit	Z7	21dB, 18, 15, 12, 9, 6, 3, 0, Off	Upper limit for video auto gain	
Black Balance	Z7	Exec	Temporary black balance, lost at power-off	
WB preset	Z7	A, B, Outdoor, Indoor, Manu WB Temp	Select A/B preset then push to balance	
WB Outdoor Lvl		-7~0~+7	Colour offset for Outdoor	
WB Temp Set		2300~15000K	Colour temperature for Manual	
ATW Sens		Intelligent, High, Middle, Low	Auto white balance, High reduces colour errors, Low increases them	
Smooth WB		Fast, Middle, Slow, Off	Speed of white balance response when changed	
AE Shift		-7~0~+7	Drive auto-exposure, -7=dark, +7=light	
AE Window	Z7	Standard, Type1~5	Various window mask shapes for auto-exposure	
AE response		Fast, Middle, Slow	Speed of auto response	
AT Iris Lmt		F11, F9.6, F8, F6.8,F5.6, F4.8, F4	Maximum aperture limit for auto exposure	F5.6[1]
ECS Freq.		50~200Hz	For ECS shutter, slowest is 25 for Progressive	
Flikr reduce		On, Off	Supposed to reduce lighting flicker	
Cntrst Enhcr		On, Off	Claims to improve high contrast scenes, e.g. backlit	
Back Light		On, Off	Compensate for back-lighting	
Spotlight		On, Off	Compensate for spot-lighting	
Steadyshot		On, Off	Set Off when on a tripod	
		Hard, Standard, Soft		
AF assist		On, Off	Use focus ring for fine focus adjust in auto-focus	
Focus Macro		On, Off	Focus within 80cm	
Handle zoom		1~3~8	Zoom speed for FIX position, 1=slow, 8=fast	
Speed Zoom	Z5	On, Off	Allows crash zoom	
D.Extender	Z7	On, Off	Digital zoom to 150%	Off
Fader		White Fader, Black Fader	Shot fades to/from black/white	
Smth Slw Rec			About 4x cranked, see manual for details	
Interval Rec			Stop-frame recording, see manual for details	
DV Frame Rec		On, Off	Records about 5 frames/push of Rec Start/Stop	
S.Trans	Z5			
Trans Time	Z5	3.5 ~ 15 sec		
Trans Curve	Z5	Soft, Stop		
Start Timer	Z5	Off, 5, 10, 20		
Rec Link	Z5	Off, Shot A, Shot B		
S.Trans/F.Mark	Z7	Shot Transition, Focus Marking	Assign Shot Trans/Focus Mark button	
x.v.Color		On, Off	Wide-gamut colour, only for compatible displays	Off
Color Bar		On, Off	Type 1=SMPTE, Type 2=ARIB, Type 3=100% full, Type 4=75% full	
	Z7	Type 1~4		1 or 2[2]
Flange Back	Z7	Auto Adjust, Manu Adjust	Back focus setting[3]	

AUDIO SET menu

item		range	comments	BBC
DV Au.Mode		FS32k, FS48k	Audio sample rate, SD	
Audio limit		Off, On	Only when in Manual audio level	
Int Mic Set	Z5		Internal mic controls	
Mic NR	Z5	On, Off	Noise reduction	

[1] In 1"/3 sensors, iris diffraction starts to be visible at about F/5.6, i.e. the picture gets softer and has chromatic aberration effects.

[2] SMPTE bars are ubiquitous, but ARIB bars have some advantages, agree the type of bars to be used with the post-production people before shooting.

[3] Backfocus setting should always be done when changing lenses, or when the camera temperature change significantly. The Zeiss lens has a calibrated back setting, so it may be possible to set the lens off the camera.

Mic Sens	Z5	Normal, High	Sensitivity	
Mic Wind	Z5	On, Off	Wind noise filtering	
XLR set			Settings for external sources	
XLR AGC link	Z7	Separate, Linked	Link for stereo (valid for Auto level only)	
AU. Man Gain	Z7	Separate, Linked	Link for stereo (valid for Manual level only)	
Input 1 Mic NR		On, Off	Noise reduction for Mic input, not Line level	
Input 1 trim		-18, -12, -6, 0dB, +6, +12dB	Mic level	
Input 1 wind		Off, On	Wind noise reduction	
Input 2 Mic NR		On, Off	Noise reduction for Mic input, not Line level	
Input 2 trim		-18, -12, -6, 0dB, +6, +12dB	Mic level	
Input 2 wind		Off, On	Wind noise reduction	
Separate/Linked	Z5	Separate, Linked	Links channels for AGC	
Audio Ch sel		Ch1Ch2, Ch1, Ch2	Ch1Ch2=stereo, Ch 1 /2 =input Ch to both	
DV Audio Mix		Ch1Ch2, Mix, Ch3Ch4	Monitoring	

DISPLAY SET. menu

Viewfinder and LCD

item		range	comments	BBC
Zebra		On, Off	Exposure metering	
Level		70~100,100+	Signal level, %	75 {f}, 100{v}
Histogram		Off, Normal, Advance	Advance adds a marker for average video level	
Peaking		On, Off	Help with focus, does not get recorded	
Colour	Z5	White, Red, Yellow	Colour of enhanced edges	
Level		High, Middle, Low	Sensitivity	
Marker		On, Off	All sorts, not available when Date Rec is on	
Centre		On, Off	Small centred cross	
Aspect		On, Off	Boundaries at 4:3, 13:9 or 14:9	14:9
Safety Zone		On, Off	Edge at 80% or 90%	
Guideframe		On, Off	Grid	
Cam Leveling		On, Off	[4]	
Exp. Focus Type		Type 1, Type 2	Expanded focus, Type 2 is in mono	
Cam Data Disp		On, Off	Shows camera settings (gain, shutter etc)	
Au. Lvl Disp		On, Off	Audio level meters, stereo	
Zoom Display		Bar, Number	Lens focal length, Number is 0~99, not much help	
Focus Disp		Meter, Feet	Focus distance	
Shutter Disp		Second, Degree	360 degrees=1/frame rate	
LCD Bright			Side lcd brightness	
LCD color			Saturation	
LCD BL level		Normal, bright	Brightness, always Bright on external power	
VF B.Light		Normal, bright	Brightness, always Bright on external power	
VF color		On, Off	Set v/f to monochrome	
VF Power Mode		Auto, On	Auto switches vf off when lcd is open	
Letter Size		Normal, 2x	Screen text size	
Remaining		Auto, On	Auto shows length of tape left on Play or Batt/Info	
Disp Output		LCD Panel, V-Out/Panel, All Output	All Output sends everywhere (VF, LCD, Analogue, HDMI, the lot)	

IN/OUT REC menu

VTR matters

item		range	comments	BBC
Rec format		HDV1080i, DV	Recoding format	
VCR HDV/DV		Auto, HDV, DV	iLink/Frewire connection format, disconnect to force system to set itself correctly	
HDV Progre.			Progressive scan format in HD	
Rec Type		Interlace, Progressive	[5]	Interlace
Scan Type		50, 25		25 {f}, 50{v}
DV Progre.			Progressive scan format in DV	
Scan Type		50, 25		25 {f}, 50{v}
DV Rec Mode		DVCAM, DV SP	SD recording format	
DV wide rec		On, Off	16:9/4:3 recording (DV only)	
Video Out			Control of component analogue output	
Component		576, 1080i/576i	Set according to TV set type	

[4] If this is what I think it is (i.e. I didn't check it) its hugely useful, a 2-d spirit level. I wonder…..

[5] Rec Type=Interlaced is the normal HDV recording format, whether progressive (psf) or interlaced (i). Rec Type=Progressive is a proprietary format for progressive recording, and will not play on all HDV players.

Downconvert		Squeeze, Letter Box, Edge Crop	For SD from HD: component, S-video, composite	
DV Wide Conv		Squeeze, Letter Box, Edge Crop	For SD playout	
i.Link Set			Control of IEEE1394 Firewire output	
HDV-DV Conv		On, Off	Set downconversion via 1394	
Down Convert		Squeeze, Edge Crop		
Ext Rec Ctrl			Control of external 1394 recorder	
Rec Ctl Mode		Off, Synchronous, Relay, Ext Only	Synch records internal/external, Relay goes external when internal tape is full	
Stby Command		Rec Pause, Stop	Stop mode for external recorder	

TC/UB SET menu

Timecode etc

item		range	comments	BBC
TC Preset			Set TC, see manual	
Preset			Enter time code, use Sel/Push Exec dial	
Reset		Exec	Reset to zero	
TC Countup		Exec	Add 1 hour, minutes=0, when TC Make=Preset	
UB Preset			Set User Bits, see manual	
Preset			Set user bits with Sel/Push Exec dial	
Reset		Exec	Reset to zeroes	
TC Run		Rec run, Free run	Free run is real time	
TC Make		Regnerate, Preset	Regen sets Rec Run	
TC Link			Sync on multiple cameras, see manual	
UB time rec		Off, On	On sets real time in User Bits	
UB-Date/TC-Time			Sets date and time into User Bits	

MEMORY SET menu

Memory Stick

item		range	comments	BBC
All Erase		All Files, Current Fldr	Pretty obvious	
Format		Exec	Wipes the lot	
File No.		Series, Reset	Series increments file numbers, Reset starts again	
New Folder		Exec	Each folder can hold 9,999 images	
Rec Folder		Exec	Select recording folder	
PB Folder		Exec	Select folder to play back	

OTHERS menu

item		range	comments	BBC
Camera Prof.			Profiles. Up to 99 on a stick, 2 in the camera	
Load		Exec	Sel/Push Exec to load a profile	
Save		Exec	Sel/Push Exec to save to stick or camera	
Change		Exec	Sel/Push Exec, select profile and edit the name	
Delete		Exec	Sel/Push Exec to select, then delete it	
Copy		Exec		
Assign Buttons	Z5	Focus, Exp Focus, Focus Macro, D Extender, Ring Rotate, Hyper Gain, AE Shift Push AT Iris, Index Mark, Steadyshot, Back Light, Spotlight, Fader, Color Bar, Smooth Slow Rec, Last Scn Rvw, Rec Review, End Search, Zebra, Marker, Peaking, Display, TC Reset, TC Countup, Photo, Picture Profile 1~6	Assign any to buttons 1~6 Factory defaults are: L1 Button=D.Extender Button 4=Zebra Button 5=AE Shift Button 6=Rec Review	
Assign Buttons	Z7	Focus, Exp Focus, One Push, Focus Infinity, Focus Macro, D Extender, Hyper Gain, Blk Balance, AE Shift, Index Mark, Steadyshot, Back Light, Spotlight, Fader, Color Bar, Last Scn Rvw, End Search, Zebra, Marker, Peaking, Display, TC Reset, TC Countup, Photo, Rec Lamp(F), Rec Lamp(R), Picture Profile	Assign any to buttons 1~6 Factory defaults are: L1 Button=D.Extender Button 4=Zebra Button 5=AE Shift Button 6=Rec Review	
Clock Set			This comes up every time the camera powers up until you set the time/date	
World Time			Select local time relative to original setting	

Language			How do you get back if you select a language you can't read? ☺	
PB Zoom	Z7	On, Off	Use zoom lever to zoom on playback, up 1.5	
Quick Rec HDV		Off, On	On is quicker, but breaks the MPEG GoP structure, may not work with some NLEs	
Date Rec		Off, On	Burns time/date onto recording	
Beep		Off, On	Warning sound on start/stop recording	
Rec Lamp (F)		On, Off	Front recording lamp	
Rec Lamp (R)		On, Off	Rear recording lamp	
Remote Ctrl		On, Off	Enables remote control	
Hours meter			VTR hours meters display	

PICTURE PROFILES menus, default settings

Camera control

item	range	comments	BBC
PP1		User=Normal	
PP2		User=Normal	
PP3		Pro Color=Professional camcorder, ITU709 gamma	
PP4		PD Color=Handy cam (I guess PD170)	
PP5		Film Look 1=Colour Negative	
PP6		Film Look 2=Colour Print	

PICTURE PROFILES menus, manual settings

Camera control

item	range	comments	BBC
Black Level			
Master Black	-15~+15	No calibration, cap the camera and use waveform monitor or Histogram to set black levels. RGB values are added to Master level	
Black R	-15~+15		
Black G	-15~+15		
Black B	-15~+15		
Gamma	Standard, Cinematone1, Cinematone2, ITU709, G5.0, PD, x.v.	G5.0 is BBC 0,4 law	ITU709[6]
Black Gamma		Black stretch	
Range	High, Middle, Low		
Level	-7+7	- is black compression, + is stretch[7]	0
Knee		Compress overexposure	
Mode	Auto, Manual		Manual
Auto Set			
Max Point	90%~100%		90%[8]
Sensitivity	High, Middle, Low		Middle
Manual Set			
Point	75%~105%		87.5%
Slope	-5~+5		-2[9]
Color Mode			
Type	Standard, Cinematone1, Cinematone2, ITU709 Mtx		ITU709
Level	1~8	Cross-fade, 1=Standard, 8=what you selected	3
Color level	-7~+7, -8	Saturation, -8=monochrome	0
Color phase	-7~+7	Greenish to reddish	0
Color Depth	-7~+7	6-axis multimatrix, set saturation for RGBCMY	0[10]
Color Correct		See manual, rather complicated	
Type	Off, Color Revisn, Color Extract		Off
Memory Sel	1, 2, 1&2	2 colour stores	
Mem1 Color		Define colour in Memory 1	
Mem1 Revisn		RB gain modification to colour in Memory 1	
Mem2 Color			
Mem3 Revisn			
WB shift		Shift aim point, - for blue, + for red	
Filter Type	LB-CC, R-B	LB-CC works on secondaries, RG on primaries	
LB Col Temp	-9~+9	Blue to red	
CC MG/GR	-9~+9	Green to magenta	
R Gain	-9~+9		
B Gain	-9~+9		
Detail			
Level	-7~+7		0 {v}, -2{f}
Manual Set	On, Off		On
V/H Balance		Set balance of horizontal to vertical detail	0

[6] 709 gives the most accurate colour rendition. The Cinematone curves give a more film-like appearance, but actually capture significantly less contrast.

[7] If Standard gamma is used, some black stretch may be a good idea, to improve colour fidelity.

[8] Although performance is usually best with manual knee set, there are clearly advantages to using automatic for simplicity. These settings should be acceptable.

[9] These settings slope the knee point to reach 250% at peak white. Thus captures the biggest contrast range the camera can do.

[10] Colour controls are best though of as a 'special effect', which is usually best done in post production where more control and better monitoring will deliver best results.

B/W Balance	Type1~5	Control positive-/negative-going detail	Type 4
Black Limit	0~+7	Limit –ve going detail, 0=limit, 7=not	3
White Limit	0~+7	Limit +ve going detail, 0=limit, 7=not	7
Crispening	0~+7		0
Hi-Light Dtl	-2~+2	Detail enhancement in high signal levels	+2
Skintone Dtl	On, Off	See manual, rather complicated	Off[11]
Level	1~8	1=less detail, 8=more	
Color Sel		Define the colour to be tweaked	
Phase	0~32~64~96~127	0=purple, 32=red, 64=yellow, 96=green, 127=blue	
Range	0~31	0=off, 1=narrow, 31=wide	
Saturation	0~31	0=mono, 31=max saturation	
Reverse		Reverses the colour selection, i.e. do all the others	
Y Level	0~31	0=dark, 31=bright	
Y Range	1~32	Brightness range, 1=narrow, 32=wide	
One Push Set		Auto adjust colour at centre marker	
Profile Name		Set a profile name	
Copy		Copy one profile into another	
Reset		Factory reset this profile	

[11] Skin tone detail may be useful on occasions, but can be tricky to set and deliver unexpected results as lighting levels change. Use with care.

2 Measurements

All measurements were made on frames captured via the HDMI output via a 10-bit HDSDI converter box (Focus Enhancements MCSDI-1: this does not filter the signals, and delivers a 10-bit HDSDI signal), to avoid the known limitations of the recording formats. The HDMI signal from the camera delivers only 8-bit data, but this was not considered to have affected the measurements in any significant way. Although not the usual practice for camera tests, this image capture process was far easier to manage, and did not lead to any confusion or misrepresentation of the camera performance.

2.1 Colour performance

The gamma curves were not explored in detail, because there is little that can be done about them. Instead, a calibrated Macbeth chart was used, correctly exposed with studio illumination. The pictures were displayed on a HD monitor and compared with another chart illuminated at D65. Frames were grabbed for analysis as well, but not used because the visual examination provided the expected results.

With the ***ITU709*** gamma-correction curve, which should be correct for HDTV, and ***Color Mode*** (i.e. matrix) set to ITU709 the colours were all somewhat oversaturated, too colourful. The cure was to set the ***Color Level*** to 3, apparently taking 3/8 of the ***ITU709*** matrix and 5/8 of the ***Standard*** matrix. Colour performance was then judged to be quite accurate, and can be expected to be very similar to the ***G5.0*** gamma-correction curve (approximately the BBC 0.4 law). This combination delivered about 1.7 stops of overexposure, making a total exposure range of about 10.5 stops with the recommended ***Knee*** settings.

The ***Cinematone*** curves were not investigated here, but are almost certainly those of the Z1. ***Cinematone 1*** should deliver about 8.9 stops, while ***Cinematone 2*** is more gentle and delivers about 8 stops. Both these curves are appropriate for shooting where grading is not expected, but scenic contrast will effectively be abandoned at the time of shooting. The recommended settings will always capture the maximum contrast, although grading will be needed to achieve any specific "look". The user is strongly advised to make tests before using these or any other settings

Black Gamma raises the gain near black by a significant amount, extending the exposure range by between 0.5 and 0.8 stops while increasing video noise levels.

The ***Standard*** curve (***Normal*** in the Z1) will deliver good colour rendering using only about 45% of the sensors' exposure range (the normal television mode), reserving the remainder of the range for highlights, significantly compressed.

If the ***Standard*** curve is to be used, some ***Black Stretch*** would be a good idea if the intention is to capture a large dynamic range and use post-processing to achieve a film look, while ***Cinetone*** curves should be used if the intention is to produce a film look without further processing, but greater attention will have to be paid to getting exposure levels exactly right.

None of the colour adjustment/correction controls were investigated, they are best thought of as "special effects", trickery.

2.2 Resolution, 1080-line

The camera specification says that it has sensors of 1.20 Megapixels, and claims dimensions of 1440x810. At this point, it makes sense to speak of photo-sites, rather than pixels, since pixels belong in the picture and not in the camera. A photo-site is equivalent to a picture element in the sensor. The relationship between camera photo-sites and image pixels is rather more complex than in most cameras.

The sensors are rotated 45 degrees, and images interpolated from the now diamond-shaped photo-sites. Thus the resolution delivered is only loosely connected with the actual 'pixel' count, and there is probably a boundary of blanked-out cells to provide information for black level control as well. The advantage of this rotated arrangement is that the coloured aliasing that results from the normal 'precision offset' arrangement (whereby the green sensor is placed exactly half a photo-site spacing from the red and blue to achieve extra resolution) is avoided, at the expense of diagonal aliasing in the luma signal.

The specification also says that there are 1,037,000 *effective* photo-sites for 16:9 video capture. If they are all square (placed on a 3.333µm grid), then the effective image dimensions for 16:9 capture would have to be about 1358x764 (1358x764=1,037,352). To confirm this, the specification also says that the *effective* number for 4:3 capture is 778,000, and 1358x3/4=1018, so the dimensions for 4:3 become 1018x764=778,134.

A circular zone plate test chart was used to explore resolutions up to exactly 1920x1080. Each pattern limits at exactly 1920 horizontally and 1080 vertically, frequencies being proportional to distance from the centre of the pattern. Measurements were made on the Z7, with confirmation tests done on the Z5.

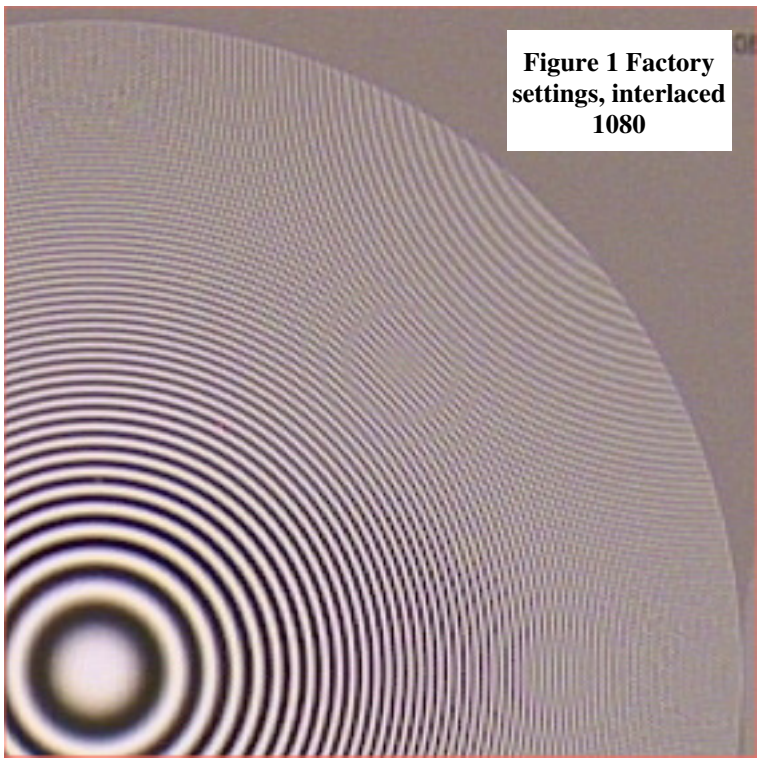

Figure 1 Factory settings, interlaced 1080

Figure 1 is one quadrant of one pattern, exploring the frequency response from dc in the centre spot to 1920 horizontally, and 1080 vertically, at the outer rim, frequency being proportional to distance from the centre. Unfortunately, during the test session the chart was not quite correctly framed at the time of image capture, and a correction must be made to allow for this, a zoom factor of 1.035, i.e the maximum frequencies explored are 1987x1118 in this case.

The capture was made with factory settings, interlaced. It shows null zone at 71.6% of the horizontal maximum, 1424. This suggests that the *effective* active area of the sensors is actually 1424 photo-sites wide, and therefore 801 high (since 1424/801=16/9), confirming the calculations in the paragraphs above.

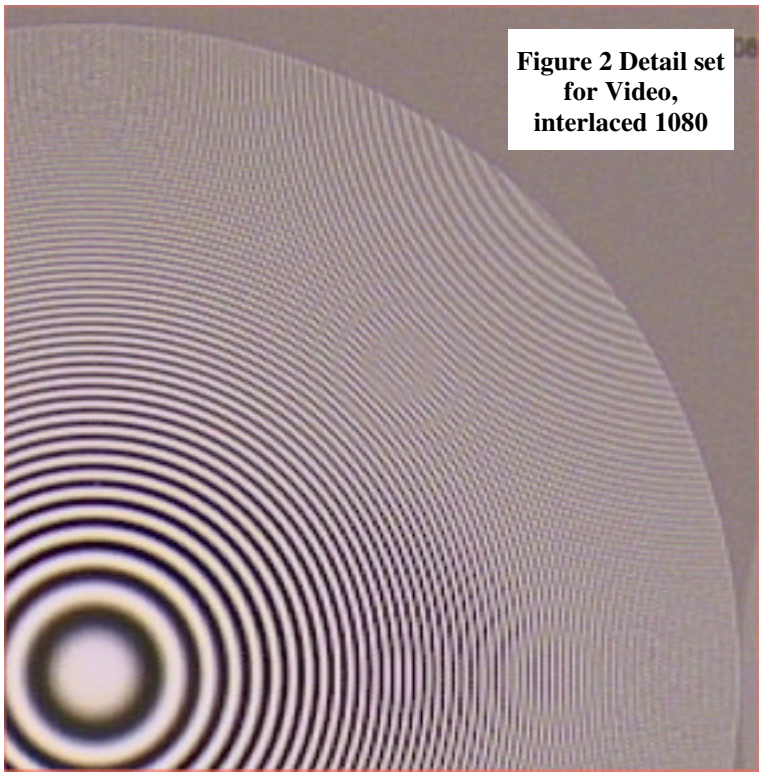

Figure 2 Detail set for Video, interlaced 1080

Horizontal frequencies beyond the null show some coloured aliasing, which indicates that the green sensor is offset from red and blue by half a photo-site even in this rotated arrangement. Vertically, there is no clear null zone, as is to be expected for an interlaced image. However, frequencies above 800 are clearly aliased, but not excessively so. But, there are strong diagonal aliases, which are common in cameras using a single Bayer-patterned sensor, and in 3-sensor cameras where the precision offset of the green from red and blue is done both vertically as well as horizontally, a quincunx arrangement. The presence of these diagonal aliases confirms that there is no optical filter in the camera between the lens and the sensors. In broadcast cameras, there are normally two bi-refringent filters, to suppress the higher horizontal and vertical frequencies that would cause aliasing in the camera. In this camera, the filters would have to be

arranged to limit the diagonal frequencies rather than horizontal and vertical. The absence of this filtering places the camera out of the broadcast HDTV field.

Figure 2 shows the recommended ***Detail*** settings for *Video*, the aliasing is more pronounced, but is not excessive. However, any further increase in the ***Detail*** settings produces little effective sharpening of the image, but worsens the appearance of the aliasing. Detail should be used with care, since aliased spatial frequencies move in the opposite direction to image motion and cause confusion in motion-sensitive compressors, such as MPEG, effectively consuming bit-rate unnecessarily.

The ***Detail*** settings for *Film* soften the pictures a little, and reduce the visibility of the aliases. The result is not shown here.

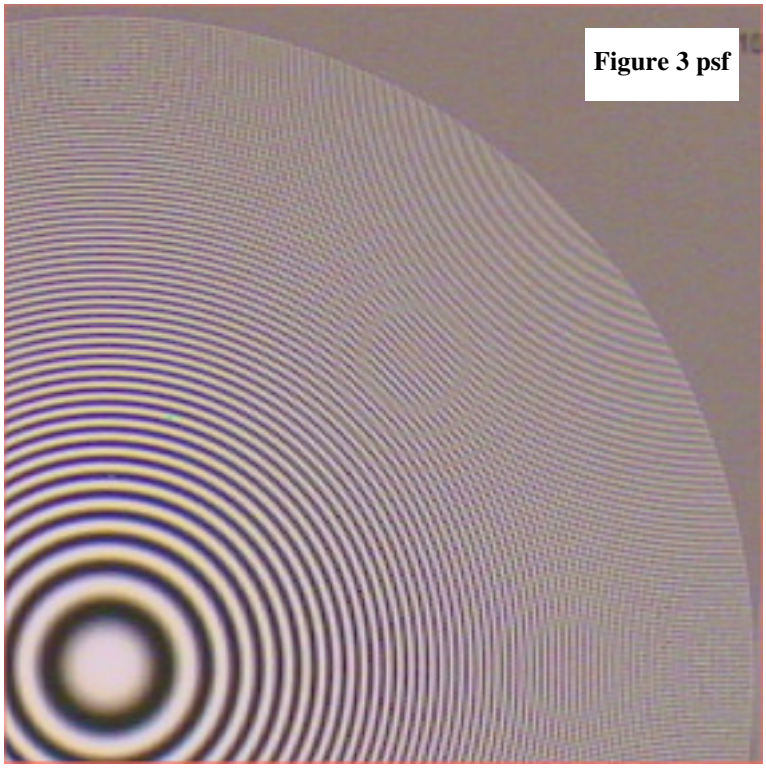

Figure 3 psf

Figure 3 shows the performance when the camera was set to ***Rec Type*** *Interlaced*, ***Scan Type*** *25 frames/second* (the standard nomenclature for this mode is psf, progressive with segmented frames). ***Detail*** was set for *Film*. Clearly, there is more vertical detail, mixed with coloured aliasing. This is the normal shooting mode for a film look, and is recorded as interlaced field-pairs although they both belong to the same temporal exposure. In this mode, the signal will travel through recording, editing, and transmission as though it were interlaced. It is only in the display that the field-pairs (frame segments) come back together to form a displayed frame. However, there can be some confusion in editing, as to which field-pair belongs together, the setting for this being known as field-dominance.

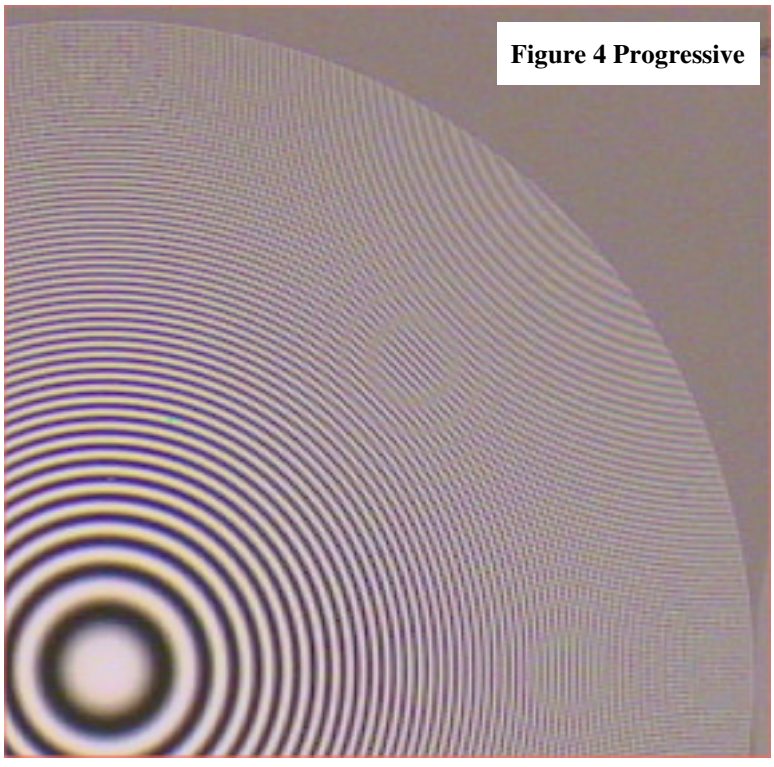

Figure 4 Progressive

Another problem with psf recording is that each field or frame-segment is separately compressed as an entity. For interlaced images, this is normal, but for progressive images it should be more efficient to compress the entire frame in one go, as is done for images at 720p. This camera has another mode, ***Rec Type*** *Progressive*, in which the entire 1080-line image is compressed as one.

Figure 4 shows the result. There is no visible difference in resolution, confirming that there is no image quality advantage in using this mode, apart from the slight advantage in recording, which should result in a slightly lower level of compression artefacts. Note that recordings made in this mode can not be played back in a standard HDV player, only in one compatible with this

recording mode.

2.3 Resolution, 576-line

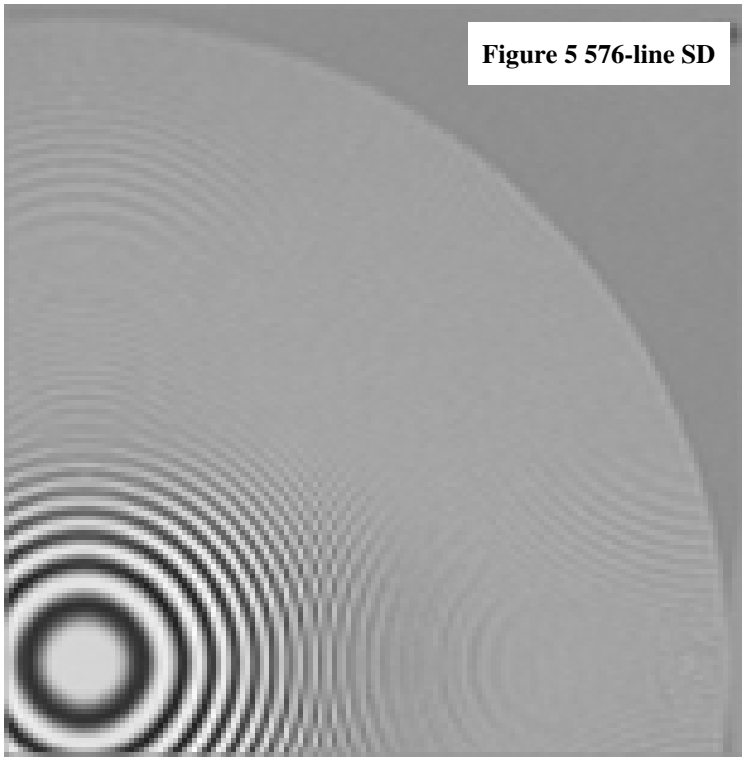

Figure 5 576-line SD

The cameras can be operated in SD mode, therefore down-converting the HD signal from 1080-line to 576. Figure 5 shows the result on the same quadrant of zone plate.

Clearly, some of the high-frequency image content, which should have been suppressed in the down-conversion, remains in the output, albeit aliased. There is a null centre at 1440 horizontally, from the sensor pixel dimensions, and diagonal aliasing at near-horizontal frequencies. Interestingly, there is no symmetrical aliasing near the vertical axis, presumably due to the interlaced nature of the output signal.

Vertically, there is a second-order alias, where frequencies have been folded twice, the zone centre shifted to 576.

Overall, the performance at SD is not particularly good, significantly better pictures should be obtained by using a proper, external, down-converter. I cannot recommend using this camera in SD mode, because of the level of these spatial aliases. However, it is significantly better than the Z1 in this respect.

2.3.1 Lens aberrations

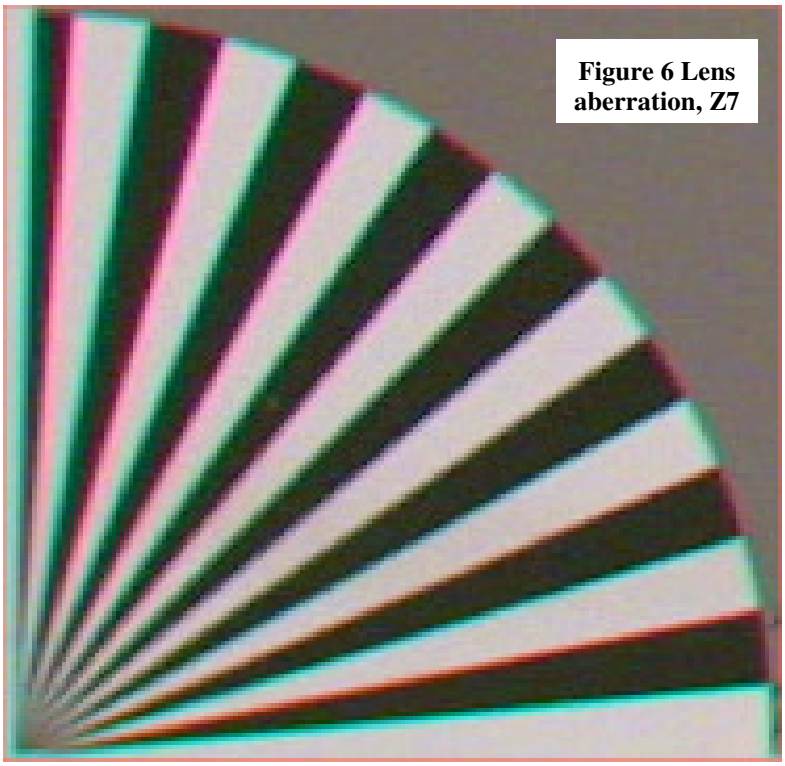

Figure 6 Lens aberration, Z7

The Zeiss lens supplied with the Z7 showed some chromatic aberration in the corners.

The spatial offset is about 4 pixels, not a very good performance for an HDTV lens. The camera's performance should be considerably better with a ½" format lens, not through increased sharpness (because lenses for larger formats do not have to be able to pass frequencies up to 200lp/mm to the sensor) but through better aberration performance. At the time of writing this document, there was only one ⅓" lens available for the camera, the one supplied with it.

The integral lens in the Z5 showed a similar degree of chromatic aberration, albeit in different colours and directions.

2.4 Video noise

The camera manual gives no specification for video noise level, but video noise plays a crucial part in pros-production operations such as matte-ing, keying and colour manipulation.

For noise level measurements, a plain white card was evenly illuminated, and captured at 1080-line resolution, interlaced, at four exposures to explore the range of signal levels. The cameras were set to +6dB gain. A software high-pass spatial filter was used to reject low frequencies and statistical analysis done to calculate the video noise levels. Figures 7 and 8 show the results, plotted in noise levels (dB vertically) against luma amplitude (percentage) horizontally. Values were obtained mathematically and are un-weighted. The differences between the cameras are trivial.

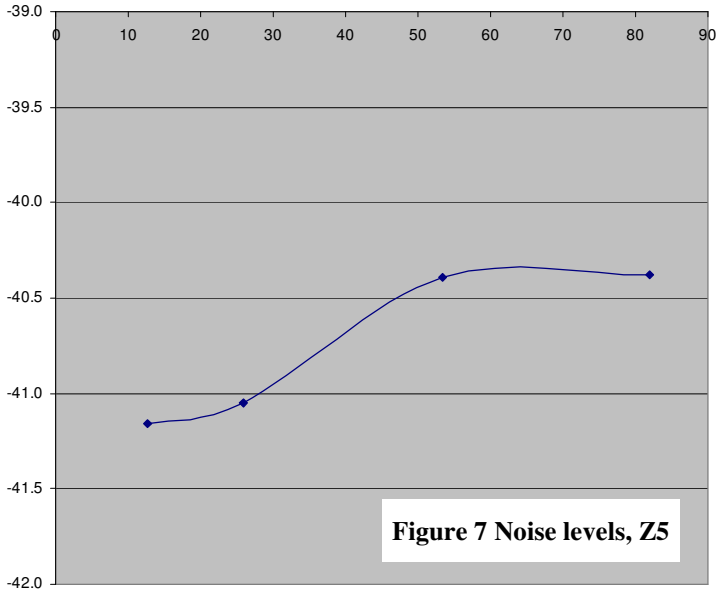

Figure 7 Noise levels, Z5

Normally, the noise level would be expected to show a strong correlation with the slope of the gamma curve since the sensor and head-amplifier noise is amplified by the differential gain (slope) of the gamma-correction, and so there should be about 10dB difference between the value around 10% and that around 90%. This cameras do not show any such correlation.

One possible explanation for this could be the use of analogue head amplifiers with limited gain-bandwidth product (i.e. cheaper). Thus, as the gain increases, the bandwidth reduces and output noise level goes down. Measurement of captured resolution is too difficult to do at low video levels (because of noise), so this explanation remains unconfirmed. However, the net result is that the noise performance appears to be better than it actually is, a desirable thing for such a camera. Perhaps this was a design decision, if so, it has worked.

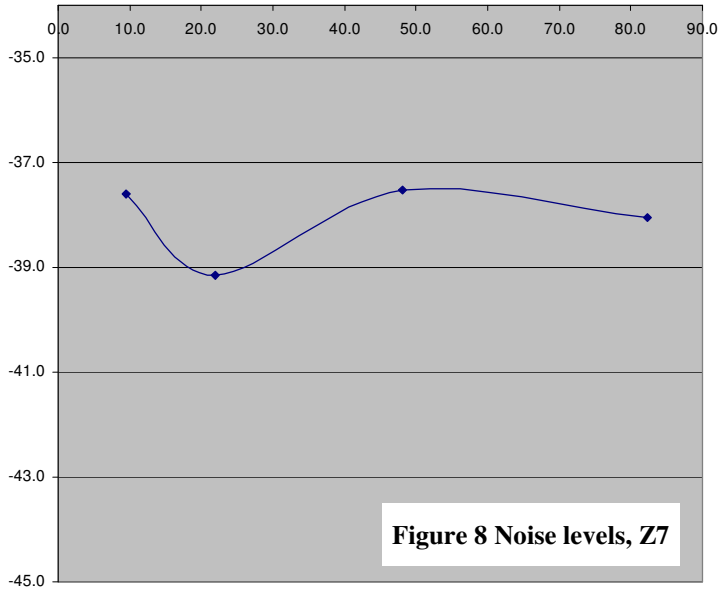

Figure 8 Noise levels, Z7

Alternatively, the sensor and head-amplifier noise could be masked by digital noise. In a professional camera, the adcs should be at least 10-bit (14-bit is common in high-end cameras), and internal processing at least 18-bit, with 10-bit recording of HDSDI output. In lower-cost cameras, reduced bit-depths can be expected, but these measurements were made at +6dB gain, so head noise should dominate, the matter is therefore unresolved.

Even so, noise performance is not up to the standards of "proper" HDTV cameras (where 54dB is expected), but the performance is not particularly bad. Compensating for the +6dB gain, the noise levels at 0dB gain should be between -43.5 and 45.2dB, about 2.5dB better than the Z1. Such noise levels are not generally a problem for simple programme production, but would be regarded as poor if the production involved any significant amount of colour-keying or matteing, for whatever reason.