

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 retail 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 1/3" 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 to 1440x810, 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 1/3". The lens mount of the Z7 is specific to the 1/3" format, but adaptors are available to permit the use of 1/2" 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 2/3" 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

Alan Roberts

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 $\frac{1}{3}$ " 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 to 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, <u>Off</u> | Speed of gain change, Off=instant | |
| Hyper Gain | | On, <u>Off</u> | On disables Backlight/Sptolight compensations | |
| AGC Limit | Z5 | <u>21dB</u> , 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 | <u>21dB</u> , 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 | | <u>Intelligent</u> , High, Middle, Low | Auto white balance, High reduces colour errors, Low increases them | |
| Smooth WB | | Fast, Middle, Slow, <u>Off</u> | Speed of white balance response when changed | |
| AE Shift | | -7~0~+7 | Drive auto-exposure, -7=dark, +7=light | |
| AE Window | Z7 | <u>Standard</u> , Type1~5 | Various window mask shapes for auto-exposure | |
| AE response | | Fast, Middle, Slow | Speed of auto response | |
| AT Iris Lmt | | <u>F11</u> , 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, <u>Off</u> | Claims to improve high contrast scenes, e.g. backlit | |
| Back Light | | On, <u>Off</u> | Compensate for back-lighting | |
| Spotlight | | On, <u>Off</u> | Compensate for spot-lighting | |
| Steadyshot | | On, Off | Set Off when on a tripod | |
| | | Hard, <u>Standard</u> , Soft | | |
| AF assist | | On, <u>Off</u> | 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, <u>Off</u> | 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, <u>Off</u> | 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 | <u>Shot Transition</u> , Focus Marking | Assign Shot Trans/Focus Mark button | |
| x.v.Color | | On, Off | Wide-gamut colour, only for compatible displays | Off |
| Color Bar | | On, <u>Off</u> | Type 1=SMPTE, Type 2=ARIB, Type 3=100% full, Type 4=75% full | 1 or 2 ² |
| | Z7 | Type 1~4 | | |
| 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 | | <u>Off</u> , 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 | Recording format | |
| VCR HDV/DV | | Auto, HDV, DV | iLink/Fwire 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 | | <u>Squeeze</u> , Letter Box, Edge Crop | For SD from HD: component, S-video, composite |
| DV Wide Conv | | <u>Squeeze</u> , Letter Box, Edge Crop | For SD layout |
| i.Link Set | | | Control of IEEE1394 Firewire output |
| HDV-DV Conv | | On, Off | Set downconversion via 1394 |
| Down Convert | | <u>Squeeze</u> , Edge Crop | |
| Ext Rec Ctrl | | | Control of external 1394 recorder |
| Rec Ctl Mode | | <u>Off</u> , Synchronous, Relay, Ext Only | Synch records internal/external, Relay goes external when internal tape is full |
| Stby Command | | <u>Rec Pause</u> , 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 | | <u>Rec run</u> , Free run | Free run is real time | |
| TC Make | | <u>Regnerate</u> , Preset | Regen sets Rec Run | |
| TC Link | | | Sync on multiple cameras, see manual | |
| UB time rec | | <u>Off</u> , 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. | | <u>Series</u> , 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, Steadyspot, 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, Steadyspot, 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 | <u>On</u> , <u>Off</u> | Use zoom lever to zoom on playback, up 1.5 | |
| Quick Rec HDV | | <u>Off</u> , On | On is quicker, but breaks the MPEG GoP structure, may not work with some NLEs | |
| Date Rec | | <u>Off</u> , On | Burns time/date onto recording | |
| Beep | | <u>Off</u> , On | Warning sound on start/stop recording | |
| Rec Lamp (F) | | <u>On</u> , Off | Front recording lamp | |
| Rec Lamp (R) | | <u>On</u> , Off | Rear recording lamp | |
| Remote Ctrl | | <u>On</u> , 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 thought 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 *Cinematone* 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

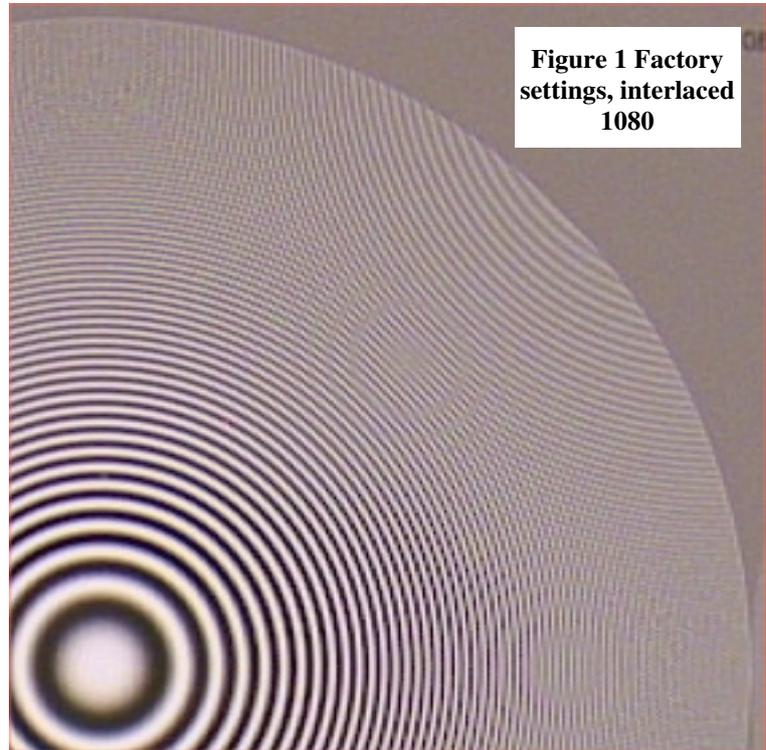
The camera specification says that it has sensors of 1.20 Megapixels, and claims dimensions of 1440x810. At this point, it makes sense to speak of photo-sites, rather than pixels, since pixels belong in the picture and not in the camera. A photo-site is equivalent to a picture element in the sensor. 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 $3.333\mu\text{m}$ grid), then the effective image dimensions for 16:9 capture would have to be about 1358×764 ($1358 \times 764 = 1,037,352$). To confirm this, the specification also says that the *effective* number for 4:3 capture is 778,000, and $1358 \times 3/4 = 1018$, so the dimensions for 4:3 become $1018 \times 764 = 778,134$.

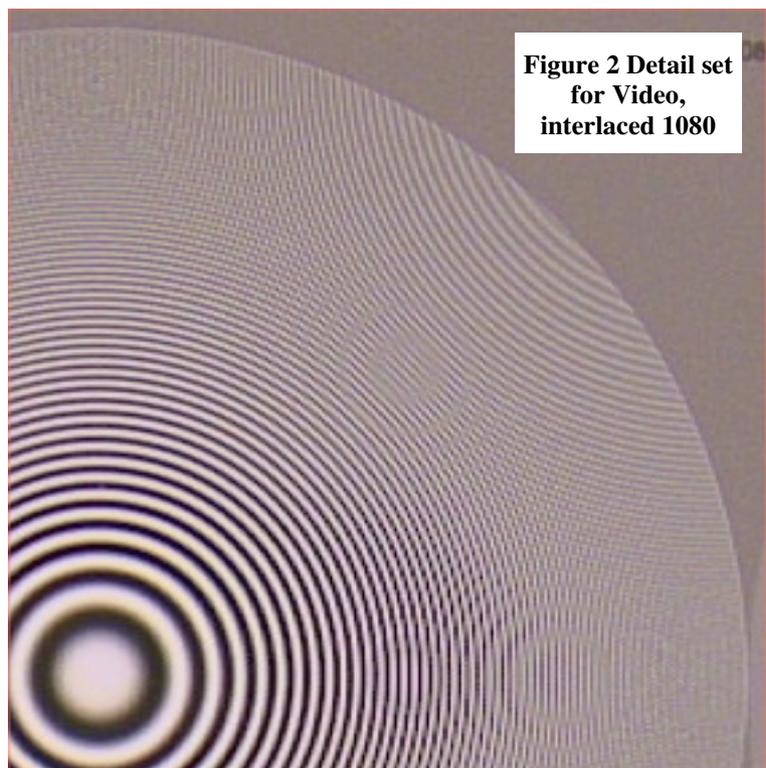
A circular zone plate test chart was used to explore resolutions up to exactly 1920×1080 . Each pattern limits at exactly 1920 horizontally and 1080 vertically, frequencies being proportional to distance from the centre of the pattern. Measurements were made on the Z7, with confirmation tests done on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

Figure 1 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 1987×1118 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.

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

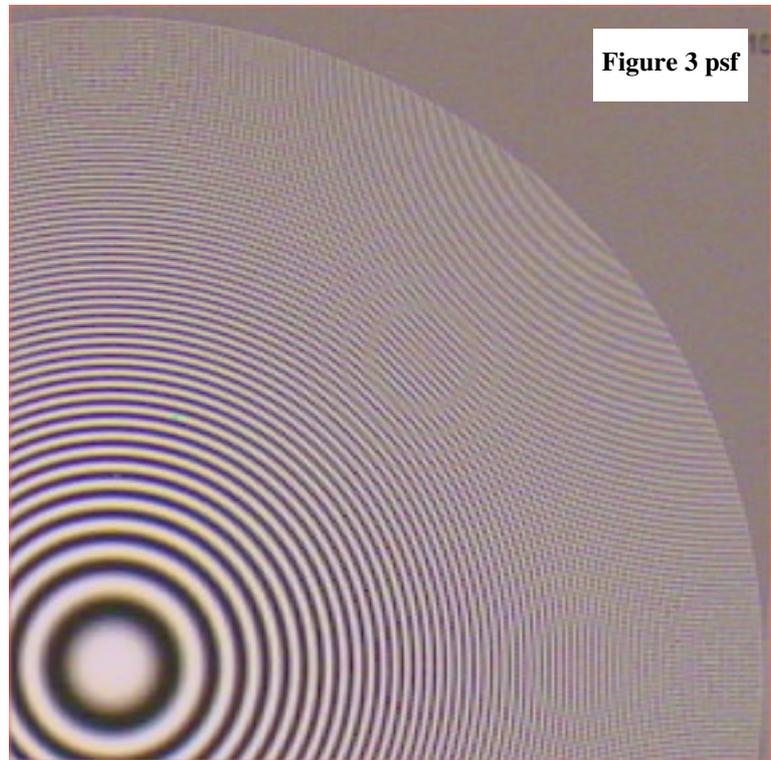


arranged to limit the diagonal frequencies rather than horizontal and vertical. The absence of this filtering places the camera out of the broadcast HDTV field.

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.

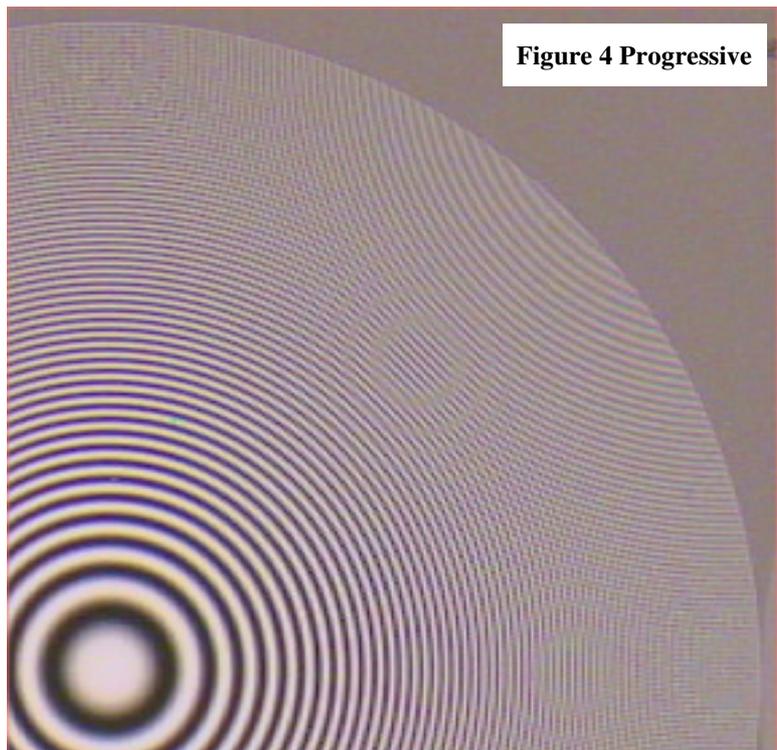
The *Detail* settings for *Film* soften the pictures a little, and reduce the visibility of the aliases. The result is not shown here.

Figure 3 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.



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

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.

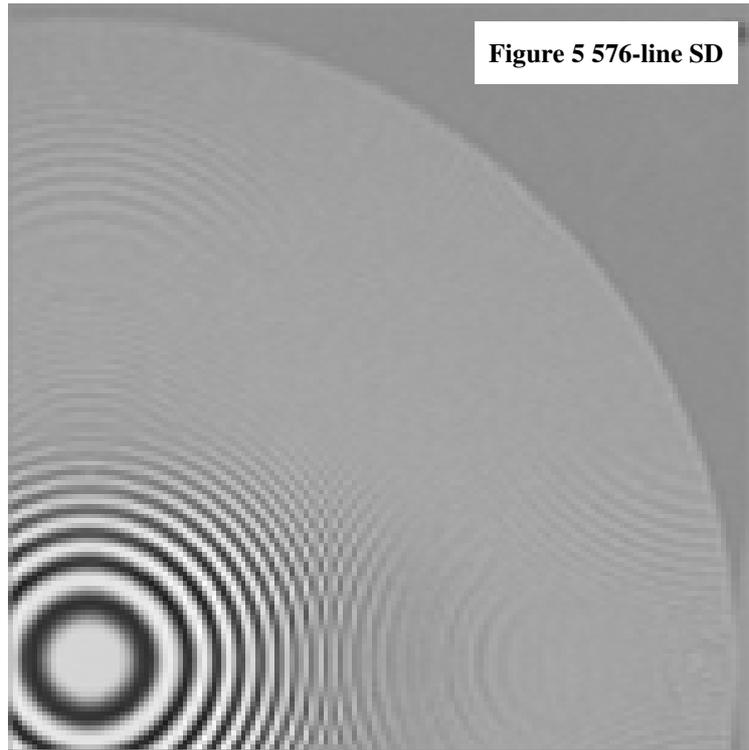


Figure 5 576-line SD

2.3.1 Lens aberrations

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 1/2" 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 1/3" 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.

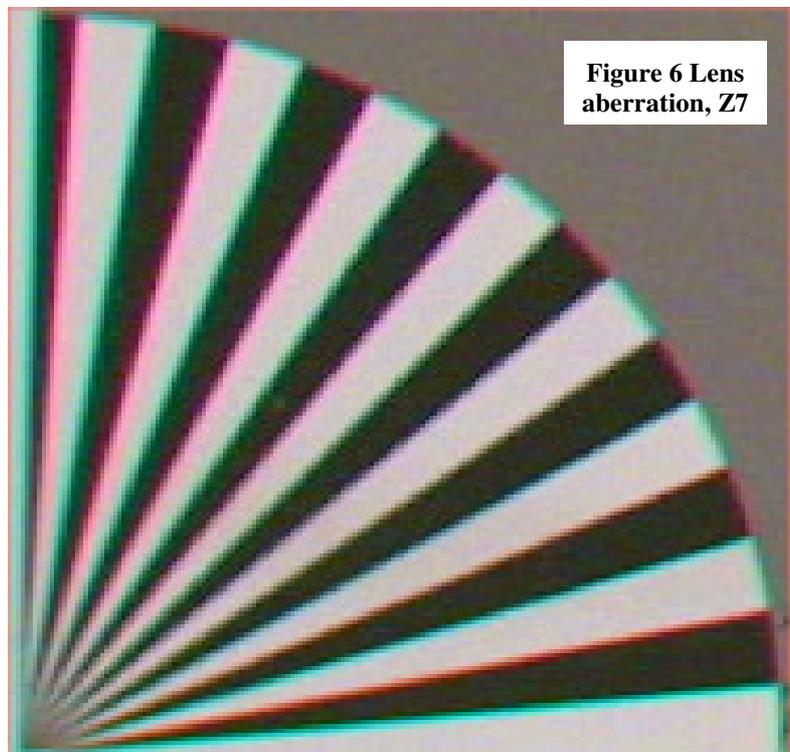


Figure 6 Lens aberration, Z7

2.4 Video noise

The camera manual gives no specification for video noise level, but video noise plays a crucial part in 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.

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.

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.

