Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 18 : Panasonic HVX200

Data for this section is taken from short examinations of two production models of the Panasonic HVX200 camcorder. This is a HDTV camcorder, physically very similar to the standard-definition DVX100, with 3 ⅓" ccds, the manual gives no clue as to the sensor resolutions. The two models under test ran only at 60 Hz (actually 59.94) or 50Hz. It records HDTV using the DVCProHD algorithm onto P2 flash cards (1080i, 1080psf, 720p), SDTV using any of the DVCPro50 or DVCPro or DV algorithms onto P2 cards (480i, 480psf, 480psfa* or 576i, 576psf, 576psfa), and SDTV onto miniDV. It can also shoot "off-speed" when recording 720p onto P2 cards, but only at spot speeds, it is not continuously variable as is the Varicam AJ-HDC27F.

The camera is relatively light and has an integral lens and viewfinder, with side lcd panel, and seems aimed at the high-end consumer/professional market rather than full broadcast, which would normally demand interchangeable lenses. It is the first tapeless camcorder for HDTV. It has a photographic speed of about 640ASA.

It has the usual internal menus for setting the performance, not as complex as in the 720-line Varicam or the 1080-line HDX400, but enough to control most of the important features. It is not suited to multi-camera operation. It has analogue-only video outputs (components at both HD and SD via a multi-pin connector) and digits via IEEE1394 Firewire and USB. This alone puts the camera in the consumer/semi-pro market, rather than broadcast, which would normally expect either HDSDI or BNC connectors for analogue.

The same assessment procedure was used as for other HD cameras, partly attempting to get a good "film-look", and the settings reflect that. It is useful to think of the camera, when used in this way, 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. The recommended settings allow about 1.3 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).

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The assessment of this camcorder was aimed mostly at discovering what it could do, rather than deriving a preferred setting, results are given in Section 2. The controls are not as flexible as for full "broadcast" cameras, so it may or may not be possible to derive a specific "film-look" for it. However, there is sufficient flexibility to achieve much of what is desirable in "film-look" settings. Photographic "speed" is about 640ASA.

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. For each item, the factory setting is given if it is known, and the range offered by the camera under test. "BBC" settings are in the last column, where appropriate. The following table shows the menu settings when the camera is in "Camera" mode, these affect picture performance; other menus are included for completeness. Values that are underlined are the factory default settings. The menus share some features with the Varicam, in that Scene Files store a great deal of information, permitting widely different settings to be stored.

BBC-preferred values are given for SD operation, for 1080 interlaced and psf, and for 720 film and sport (where sport covers all uses that are not intended to look like film). Items that have an important affect on picture appearance are highlighted. Some items are valid only for tape- or P2-operation, all items are flagged. It is unfortunate that the colour bars that the camera generates are only 100/0/75/0 (i.e. EBU) rather than the much more useful SMPTE bars that are ubiquitous in HDTV.

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

1 Menus and Settings

CAMERA MENU	
SCENE FILE	Camera operational controls, needs lab work to get the best from these
CAMERA SETUP	Basic camera setup controls
SW MODE	Configuration of switches
AUTO SW	Control of camera automatic features
RECORDING SETUP	Tape and P2 card controls
AV IN/OUT SETUP	Configure audio/video connections
DISPLAY SETUP	Viewfinder and LCD panel settinmgs
CARD FUNCTIONS	P2 flash card controls
OTHER FUNCTIONS	Sundries that don't fit anywhere else
OPTION MENU	Control of IEEE1394 (Firewire) connection

MCR/VCR MENU	
RECORDING SETUP	Timecode, IEEE1394, User bits audio, etc
PLAYBACK FUNCTIONS	Audio matters
AV IN/OUT SETUP	Analogue connection and IEEE1394 settings
DISPLAY SETUP	Viewfinder and LCD panel settings
OTHER FUNCTIONS	Sundries that don't fit anywhere else
OPTION MENU	Control of IEEE1394 (Firewire) connection

DUBBING MODE MENU	
RECORDING SETUP	Timecode, IEEE1394, User bits audio, etc
DUBBING SETUP	Format, pulldown etc

CAMERA MENU

SCENE FILE (1-6)	mode		range	comments	BBC
Operation type (P2, tape)	Camera		Video/Film	Also sets SynchroScan indicator to time or angle	
Frame rate (P2)	Camera	60	12, 18, 20, 22, 24, 26, 30, 32, 36, 48, 60	Shooting speeds for 720p only	
		50	12, 18, 20, 23, 25, 27, 30, 32, 37, 48, 50		
Synchro scan (P2,tape)	Camera		1/n~1/249.8	n=frame rate, or degrees for FILMCAM, will not set longer than 1/field or frame	
Detail level (P2,tape)	Camera		-7~+7	Horizontal and vertical edge detail	0 (1080i) -2 (1080p) +2 (720sport) -4 (720film) 0 (SD)
V Detail level (P2,tape)	Camera		-7~+7	Vertical edge detail	-2 (1080i) -4 (1080p) +3 (720sport) 0 (720film) -2 (SD)
Detail coring (P2,tape)	Camera		-2~+7	Noise limiting for detail	+4
Chroma level (P2,tape)	Camera		-7~+7	Saturation	0
Chroma phase (P2,tape)	Camera		-7~+7	Hue	0
Color temp (P2,tape)	Camera		-7~+7	Fine white balance offset	
Master Ped (P2,tape)	Camera		-15~+15	Master black lift	
A. Iris level (P2,tape)	Camera		-4~+4	Auto iris gain	
News gamma (P2,tape)	Camera		On/Off	Adds some extra knee to cope with highlights	Off
Gamma (P2,tape)	Camera		HDnorm, Low, SDnorm, High, B.press, Cine-likeD, Cine-lineV	HDnorm= ITU709, Low=high contrast (skin press), SDnorm=DVX100, High=black stretch, B.press crushes, CineV=more contrast than CineD	HDnorm (HD), High (SD)
Knee (P2,tape)	Camera		Auto, Low, Mid, High	Reaches ~ 250%, knee at 80%,90%, 100%	90%
Matrix (P2,tape)	Camera	60	Norm, Enriched, Fluo, Cine-like	Not specifically tested	Norm/ Norm1
		50	Norm1, Norm2, Fluo, Cine-like		
Skin tone detail (P2,tape)	Camera		On, Off	Reduces skin detail	Off
V Detail freq (P2,tape)	Camera		Thin, Mid, Thck	Thin and Mid may cause twitter	Thin
Name edit (P2,tape)	Camera			Names the selected scene file	
Save/init (P2,tape)	Camera		Save, Initial	Save changes, or factory reset	

CAMERA SETUP	mode		range	comments	BBC
Aspect conv (P2,tape)	Camera		Normal, Letter box, Squeeze	Recording format for 480-line	
Setup (P2)	Camera	60	0%, 7.5%	Composite black level for NTSC output	
Setup (tape)	Camera	60	0%, 7.5%	Composite black level for NTSC output	
Mid gain (P2,tape)	Camera	60	0, 3, 6, 9, 12dB	12dB gain is fairly noisy and visibly soft, probably not acceptable	3dB
High gain (P2,tape)	Camera	60	0, 3, 6, 9, 12dB		6dB
ATW (P2,tape)	Camera	60	Ach, Bch, Prst, Off	Assign AutoTrackWhite to gain switch	
Handle zoom (P2,tape)	Camera	60	L/Off/H, L/M/H, L/OFF/M	Set zoom speed switch settings,	
Iris dial (P2,tape)	Camera	60	Down open, Up open	Reverses iris control (when Manual)	

SW MODE	mode		range	comments	BBC
Mid gain (P2,tape)	Camera	50	0, 3, 6, 9, 12dB	12dB gain is fairly noisy and visibly soft, probably not acceptable	3dB
High gain (P2,tape)	Camera	50	0, 3, 6, 9, 12dB		6dB
ATW (P2,tape)	Camera	50	Ach, Bch, Prst, Off	Assign AutoTrackWhite to gain switch	
Handle zoom (P2,tape)	Camera	50	L/Off/H, L/M/H, L/OFF/M	Set zoom speed switch settings,	
Iris dial (P2,tape)	Camera	50	Down open, Up open	Reverses iris control (when Manual)	

User 1,2,3 (P2,tape)	Camera		RecCheck, Spotlight, Backlight, Blackfade, Whitefade, ATW, ATWon/off, Gain18dB, FocusRing, IndexMemoP2, SlotSelP2, ShotMarkP2	Assign user switches. 18dB works only with 60Hz formats, and not with slow shutter. P2 options label shots, change slots etc. Default:1=Whitefade, 2=Backlight, 3=Index/Memo	

AUTO SW	**mode**		**range**	**comments**	**BBC**
A.Iris (P2,tape)	Camera		On, Off	Auto iris	
AGC (P2,tape)	Camera		6dB, 12dB, Off	Set auto gain maximum	
ATW (P2,tape)	Camera		On, Off	AutoTrackWhite	
AF (P2,tape)	Camera		On, Off	AutoFocus, disables Focus/Push Auto	

RECORDING SETUP	**mode**		**range**	**comments**	**BBC**
Rec format (P2)	Camera	60	1080i/60i, 1080i/30p, 1080i/24p, 1080i/24pa[1], 720p/60, 720p/30, 720p/24, 720p/30pn[2], 720p/24pn, 480i/60i, 480i/30p, 480i/24p, 480i,24pa	Recording format for P2 card, this terminology is non-standard, but the meaning is clear.	
		50	1080i/50i, 1080i/250, 720p/50p, 720p/250, 720p/25pn, 576i/50i, 576i,25p		
Rec format (tape)	Camera	60	480o/60i, 480i/30p, 480i/24p, 480i/24pa	Tape recording format	
		50	576i/50i, 576i/250		
480i rec mode (P2)	Camera	60	DVCPro50, DVCPro, DV	Tape compression system	
576i rec mode (P2)		50			
Rec function (P2)	Camera		Normal, Interval, One shot, Loop	Non-standard recording functions	
One-shot time (P2)	Camera		1F, 2F, 4F, 8F, 16F, 1s	Frames or time to record	
Interval time (P2)	Camera		2F,4F,8F,16F, 1s, 2s, 5s, 10s, 30s, 1m, 5m, 10m	Frames/seconds/minutes	
Prerec mode (P2)	Camera		On, Off	Memory cache for prerecording	
Rec speed (tape)	Camera/ Vcr/Dub		SP, LP	Tape speed	
Audio rec (tape)	Camera, Vcr		32k12bit, 48k/16bit	The usual	
Mic alc (P2/tape)	Camera		On, Off	Auto level control	
Mic gain 1 (P2/tape)	Camera		-50dB, -60dB	External mic level control	
Mic gain 2 (P2/tape)	Camera		-50dB, -60dB	External mic level control	
25M rec ch sel (P2)	Camera		2ch, 4ch	DV/DVCPro25 sound channels	
1394 TC regen (P2/tape)	Mcr/Vcr		On, Off	On=TC from 1394, Off=other controls	
TC mode (P2/tape)	Camera/ Mcr/Vcr / Dub	60	DF, NDF	Only relevant in the 59.94Hz variant, 24p uses NDF	
TCG (P2/tape)	Camera/ Mcr/Vcr / Dub		Free run, Rec run	TC runs free or only when tape runs	
First rec TC (tape)	Camera/ Vcr/ Dub		Regen, Preset	Select TC used at start, Regen reads tape and continues	
TC preset (P2/tape)	Camera/ Mcr/Vcr / Dub			Set initial TC, when recording 24p, set frame to multiple of 5 for it to make sense	

[1] **psfa** is the slightly improved variant of the 2:3 pulldown process used to derived 60 fields from 24 frames. Conventionally, 2 fields are made from one frame, then 3 fields from the next; this results in video frames grouped in sequences of 5, only two of which contains only information from one source frame, the others contain information from 2 source frames. In this variant, the pulldown sequence is 2:3:3:2, such that only 1 video frame in a group of 5 contains information from 2 source frames. This solves many problem in production and distribution, while somewhat attenuating the uneven progress of motion caused by the 2:3 process.

[2] **pn** mode records only new frames, for over/undercranking, i.e. there is no frame repetition.

1394 UB regen (P2/tape)	Mcr/Vcr		On, Off	Source of UserBits	
UB mode (P2/tape)	Camera/ Mcr/Vcr / Dub		User, Time, Date, TCG, FrmRate	FrameRate uses a code, refer to manual	
UB preset (P2/tape)	Camera/ Mcr/Vcr / Dub			Set info, select User in UB mode	
1394 In preset (P2/tape)	Mcr/Vcr		On, Off	Sync TCG to 1394 when TCSet pressed	

PLAYBACK FUNCTIONS	**mode**		**range**	**comments**	**BBC**
32k audio (tape)	Vcr		ST1, ST2, Mix	Route stereo 1/2 or 3/4 to output when 32k	
Audio out (P2)	Mcr.Vcr		Ch1Ch2, Ch1, Ch2, Ch3Ch4, Ch3, Ch4	Channels 3 and 4 available only on P2 recording	
Audio out (tape)					

PLAYBACK FUNCTIONS	**mode**	**60**	**range**	**comments**	**BBC**
Format sel (P2)	Dub	60	1080i/60i, 1080i/30p, 1080i/24p, 1080i/24pa, 720p/60p, 720p/30p, 720p/24p, 720p30pn, 720p/24pn	Clip format for dub playback	
Pulldown sel (tape)	Dub	60	24p, 24pa	23 or 2332 pulldown to 60	
Setup (tape)	Dub	60	0%, 7.5%	Composite setup for NTSC	

DUBBING SETUP	**mode**	**50**	**range**	**comments**	**BBC**
Format sel (P2)	Dub	50	1080i/50i, 1080i/25p, 720p/50p, 720p/25p, 720p/25pn	Clip format for dub playback	

AV IN/OUT SETUP	**mode**		**range**	**comments**	**BBC**
Cmpnt out sel (P2)	Camera/ Mcr		720p, 1080i, 480i	720p converts only to 1080i	
HP mode (P2,tape)	Camera		Live, Recording	Headphone feed, use Live for off-speed	
A.dub input (tape)	Vcr		Mic, A.In	Take sound from mics or audio I/O	
1394 out (tape)	Vcr		On, Off	On feeds analogue inputs to 1394, adc	

DISPLAY SETUP	**mode**		**range**	**comments**	**BBC**
Zebra detect 1 (P2,tape)	Camera		50%~105% by 5%	Default 80%, left-leaning zebra	
Zebra detect 2 (P2,tape)	Camera		50%~105% by 5%, Off	Default 100%, right-leaning zebra	
Marker (P2,tape)	Camera		On, Off	Press Zebra button to display markers	
Safety zone (P2,tape)	Camera		Off, 90%, 4:3		
Video out OSD (P2,tape)	Camera		On, Off	Screen info to video output, beware, it goes to 1394 as well	
Date/Time (P2,tape)	Camera/ Mcr/Vcr		Off, Time, Date, Time&Date	What to show on screen	
Level meter (P2,tape)	Camera/ Mcr/Vcr		On, Off	Audio levels on screen	
Zoom, focus (P2,tape)	Camera		Off, Number, mm/feet, mm/mm	Show real distances (maybe☺)	
Card/Tape, Batt (P2,tape)	Camera/ Mcr/Vcr		On, Off	Remaining capacity	
Other display (P2,tape)	Camera/ Mcr/Vcr		Off, Partial, All	Display info depth	
Camera data (P2,tape)	Mcr/Vcr		On, Off	Show camera settings on playback	
LCD backlight (P2,tape)	Camera/ Mcr/Vcr		High, Normal	Brightness	
LCD set (P2,tape)	Camera/ Mcr/Vcr			Panel, set brightness, contrast, colour	
EVF set (P2,tape)	Camera/ Mcr/Vcr			V/F, set brightness, contrast, colour	
Self shoot (P2,tape)	Camera		Normal, Mirror	For when panel is forward-facing	

EVF mode (P2,tape)	Camera/ Mcr/Vcr		On, Auto	Auto switches off V/F when panel is open	
Display aspect (P2,tape)	Camera/ Mcr/Vcr		Auto, 4:3	Widescreen always appears letterboxed	
EVF color (P2,tape)	Camera/ Mcr/Vcr		On, Off	For black/white V/F	

CARD FUNCTIONS	**mode**		**range**	**comments**	**BBC**
Scene file (P2)	Camera		Read, Write	Save up to 4 scene files to P2 card	
User file (P2)	Camera		Read, Write	Save up to 4 file settings (not Scene) to SD card	
SD card format	Camera				

OTHER FUNCTIONS	**mode**		**range**	**comments**	**BBC**
Remote (P2,tape)	Camera/ Mcr,Vcr		Vcr1, Vcr2, Off	Remote control access	
1394 control (P2,tape)	Camera		Off, Ext, Both Chain	Backup via 1394, Ext controls remote deck with Start/Stop, Chain uses remote deck as extra recorder	
1394 cmd sel (P2,tape)	Camera/ Vcr		RecP, Stop	Set remote deck to stop or pause	
End search (tape)	Camera/ Mcr		Blank, Rec End	Search for unrecorded slot or last recording	
PC mode (P2)	Camera/ Mcr		USB device, 1394 device, 1394 host	1394 host controls external deck for backup	
Rec lamp (P2,tape)	Camera		Off, Front, Rear, Both		
Access led (P2)	Camera/ Mcr		On, Off	Card access indicator	
Beep sound (P2,tape)	Camera		On, Off	Warns of card/tape full, no tape, condensation, problem	
Clock set (P2,tape)	Camera/ Mcr/Vcr			Set clock and calendar. Really, honest, that's what it does	
Time zone (P2,tape)	Camera/ Mcr/Vcr		-12~+13	Time zone offset from GMT, for foreigners	
Power Save (P2,tape)	Camera		On, Off	Disables 5-minute inactive shut-down	
Language (P2,tape)	Camera/ Mcr/Vcr		English, Japanese	Menu language, use with care	
User file (P2,tape)	Camera/ Mcr,Vcr		Load, Save, Initial	Power down/up to activate change	
Hour meter	Camera/ Vcr			Shows head hours (5 digits per hour)	

Press Disp/Mode Chk button and Menu, then Menu to cancel

OPTION MENU	**mode**		**range**	**comments**	**BBC**
1394 status (P2,tape)	Camera/ Mcr/Vcr			**P2**: Format, rate, 50/60, channels, speed, status, video, audio **Tape**: Format, rate, 50/60, channels, speed, mode, Rx, Tx	
1394 config (P2)	Camera/ Mcr		Dflt, 1~255	1394 extended menus	

2 Measurement results

The HVX200 has no built-in test signal generator. This alone sets it apart from most professional and broadcast cameras. Thus all measurements had to be made the hard way, using optical test cards and an awful lot of data processing. Only the 50Hz version was measured in detail, serial number C6TC0015-R.

2.1 Transfer characteristic (gamma-correction)

Measurements were made to determine the equations of two of the gamma-correction curves, which also revealed the nominal exposure range of the camera. A Macbeth (Fig.1) chart was evenly illuminated, and recordings made at the full range of exposures. The bottom row of colour patches on the chart forms a grey scale, and the optical density of each patch is given in the specifications of the card, thus it was possible to obtain a large number of measurement points to form a point-wise plot of the gamma-correction curves. Since the iris control is continuous, it was not possible to set exposure precisely for each exposure, nevertheless, judicious adjustments in the data processing has provided a reasonable data set from which to estimate the gamma-correction curves.

Figure 1, Macbeth chart

Fig. 2 shows data points for the *Hdnorm* curve (supposed to be the ITU.709 curve) with *Knee* set to *Mid* (which is supposed to break at 90% voltage). It is relatively easy to fit a curve to these points, but it is not easy to be accurate since there is clearly some inconsistency in the data, caused by video noise, slightly uneven illumination, lens vignetting when fully open, imprecise setting of the iris, and so on.

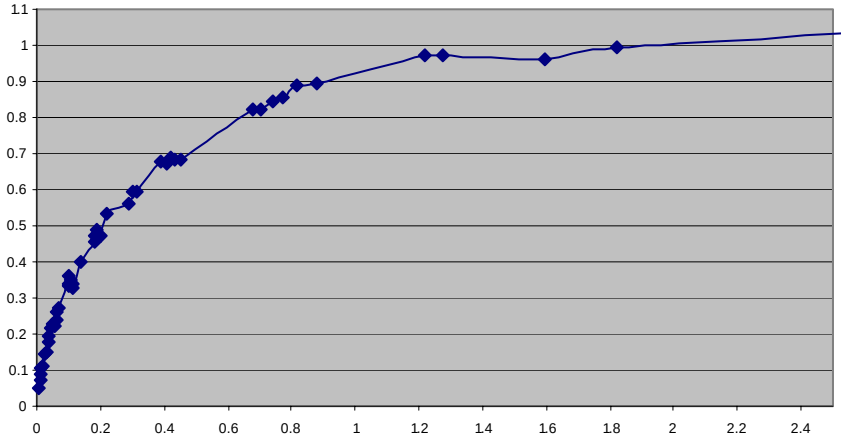


Figure 2, HDnorm gamma, Knee=Mid

The ITU.709 curve, the standard for all HDTV cameras is:

$$V = 4.5L \text{ for L<0.018, else } V = 1.0099L\text{^}0.45 - 0.099$$

The found equations for the *Hdnorm* curve are:

$$V = 4.5L \text{ for L<0.03, else } V = 1.05L\text{^}0.5 - 0.05$$

This is a reasonable match to ITU709, but is not perfect. The Knee causes the curve to break at signal levels of 80% (Low), 90% (Mid), 100% (High) and then extend to and exposure limit of 2.5 (250%) before clipping occurs at about 107%.

The contrast range for these settings is derived from the equations. The maximum exposure the camera can handle is 250%, while the minimum exposure that is visible in the output can be defined as that which causes the signal voltage to be 2% of the coding range (the video level of the super-black bar in SMPTE colour bars, used for setting display black level). If the noise is low, then a lower point can be taken, 1% would be the normal minimum considered relevant. For the *Hdnorm* curve, these ratios are approximately 550:1 (9.1 stops) and 1100:1 (10.1 stops), not bad for a camera in this category. Measurements of the High (Black Stretched) gamma-correction curve were surprising, the found equations are:

$$V = 5L \text{ for L<0.02, else } V = 1.25L\text{^}0.33 - 0.25$$

However, the numbers in this equation are a little extreme, so in a second search a rather better match to the data was found by fitting the BBC 0.4 law to it:

$$V = 5L \text{ for L<0.02262, else } V = \left(\left(L - 0.037703\right)/\left(1 - 0.037703\right)\right)\text{^}0.4$$

Both these curves fit the data well, but the BBC curve (which was designed for SDTV use) seems more natural, and is presumably intended to be so. This gamma-correction curve generally produces more accurate colour rendering. Fig. 3 shows the colour accuracy of the camera using the *Hdnorm* curve; each colour is shown as a blob where it should be and a cross where the camera produces it. There are significant saturation and hue errors, most significantly in skin tones.

The user should generally choose one of these two curves for working in HDTV, *Hdnorm* produces more vivid colouring while *High* is more accurate. For normal use, *Knee* can be set to *Auto*, but when the production will be going to a colour grading operation, *Knee* should be set either to *Mid* or *Low*, depending on the type of programme (*Mid* for programmes where skin tone is prevalent, *Low* for natural-history).

The other variants of the gamma curve were not investigated, the descriptions given in the manual seem to be sufficiently accurate and explicit for the user to make an intelligent choice.

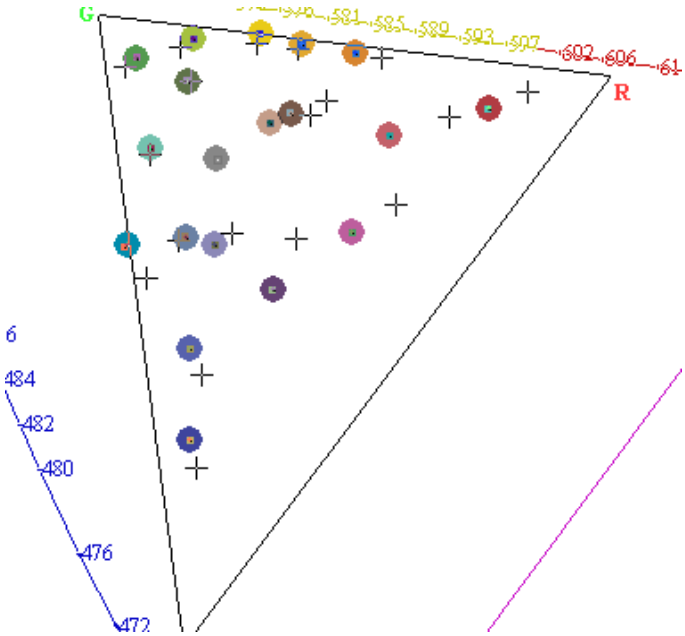


Figure 3, chromaticity of *HDnorm* curve

2.2 Resolution and Detail

The HVX200 is interesting in that the sensors are not native-sized for HDTV. The 3 ccds are each 960 by 540 pixels; it would be more usual to find sensors, in a 1080-line camera, having 1080 lines rather than only 540. Panasonic chose to use these lower-resolution sensors in order to increase sensitivity (since the pixels are bigger, the same 5µm square dimension as is found in ⅔" format HDTV cameras. The camera delivers HDTV resolutions by physically offsetting the G sensor from R and B by a half-pixel both horizontally and vertically. It is normal to offset just horizontally, when the delivered horizontal resolution is apparently about 50% higher than would be dictated by the pixel count alone. This quincunx offset increases both horizontal and vertical resolution, just how well can only be judged by measurement. This particularly relevant since the camera delivers signals at 1080, 720 and SDTV (both 576 and 480 lines in the two variants).

A zone plate test chart was used, calibrated for 1920x1080 HDTV. It contains 6 identical circular patterns, each being a phase space of the spatial-frequencies which such a camera should resolve. Analysis was made of one zone to investigate the frequency responses and the presence of aliases.

2.2.1 Detail enhancement

However, a broad pulse (also on the zone plate test chart) was used for establishing reasonable detail settings, since the function of the detail enhancement is to sharpen edges rather than establish flat frequency responses. Fig.4 shows the effect of setting *Detail Level* to 0 and –2, there was no setting at which the overshoots were absent, and insufficient other controls to alter the way the enhancement works. Judging by eye, setting level –2 seemed reasonable.

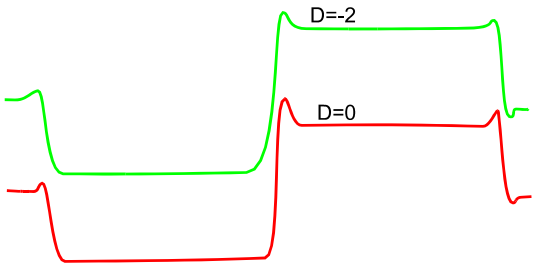


Figure 4, 1080-line pulse response

2.2.2 Resolution (1080-line)

Fig.5 shows a quarter of one circular zone plate, with zero-frequency at bottom left. The right-hand extreme is 1920 lines/picture width, the top extreme is 1080 lines/picture height. The alias patterns are clear, and indicate that the camera does not deliver full resolution at 1080, either horizontally or vertically. However, it is reasonably well behaved, in that there do not appear to be significant aliases centred on other frequencies, as would be expected if the interpolation process from the 960x540 of the ccds were compromised in any way. The precision-offset of the sensors in cameras is normally only horizontal, which delivers approximately 50% more horizontal resolution than the pixel-count, but with sensors in quincunx arrangement both horizontal and vertical resolutions are increased, but how well and by how much is debatable.

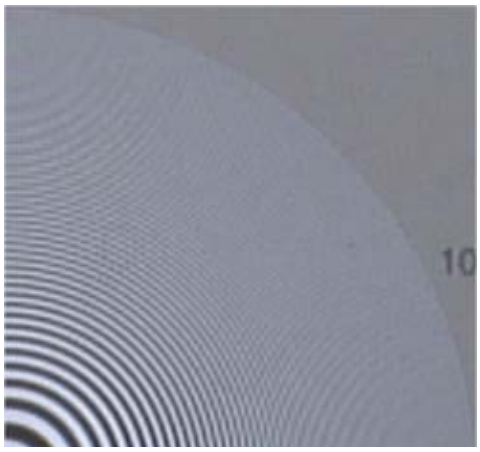
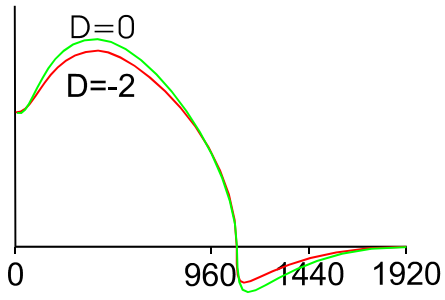


Figure 5, quarter zone plate, 1080psf/25, detail=-2, v.detail=-4

The strength of the existing aliases mean that it is difficult to measure the frequency responses accurately, since the higher frequencies are mixed with aliases. Nevertheless, it was possible to extract sufficient data using a software analysis program, to derive both horizontal and vertical frequency responses, and these reveal some interesting information.

Figs.6 and 7 show the horizontal and vertical responses for 1080i/25p (usually known as 1080psf/25, film style). It is difficult to decide how to present the amplitudes at greater than 960 horizontal and 540 vertical. It is clear that aliases (unwanted) are present, but so is content at baseband (wanted) frequencies. Since the recording format has a horizontal limit of 1440, not 1920, horizontal frequency content above 1440 must be only alias, there can be no baseband content.



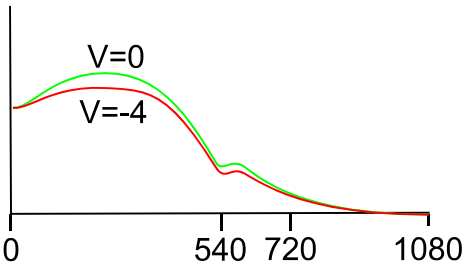


Figure 6 and 7, horizontal and vertical responses, 1080psf

In both figures, the green curve shows the response when both *Detail Level* and *Vertical Detail* are set to 0, the default value. Clearly, the designers have realised that it is more dangerous to have excess vertical detail over horizontal, but both curves seem excessively boosted at low/mid frequencies; it is in these low/mid frequencies that detail must be well controlled in order to generate a decent "film-look", neither of these curves will do. To show how difficult it is to interpret the available measurements, Fig.8 shows the sequence of sample levels in a horizontal scan.

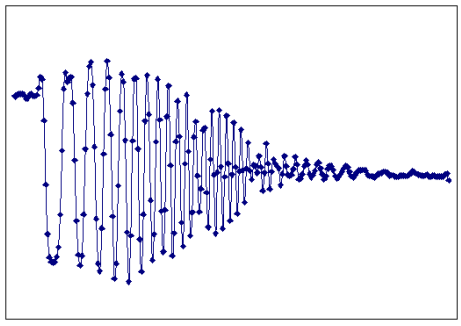


Figure 8, horizontal waveform

The settings given in Section 1 are not ideal; they are subjectively a reasonable compromise, but overall performance of the camera is not a good match to other HDTV cameras in this respect.

2.2.3 Resolution (576-line)

Again, interpretation of data is difficult, but the subjective appearance of resolution is reasonable. Fig.9 shows the horizontal frequency response. The bandwidth is well filled to the 720-pixel limit

(perhaps too well filled), but there are significant aliases between 720 and 1440, and the frequencies between 1440 and 1920 show strongly because they are twice-folded.

Evidently the *Detail* controls apply only detail-boosting (some HDTV cameras have detail controls that allow detail reduction as well as boosting). For SDTV use boosting is largely unnecessary, so a very low setting is reasonable, in Fig.9 the *Detail* setting level is 0, and is clearly too much. Judging by eye, a setting level of –2 is the maximum that should be used, and –4 looks better although the picture then starts to look soft because the boosting is done at too low a frequency even in the *Thin* setting. The settings in the table produce pictures that look sharp at the expense of some visible boundary enhancement.

Figure 9, horizontal response

The same does not hold for the vertical response, Fig.10, the response falls nicely to zero between 288 and 576, resulting in a moderate amount of interline twitter. The complete lack of vertical aliases at higher frequencies is good evidence that the camera can be used to shoot SDTV pictures, provided *Detail* is set sufficiently low.

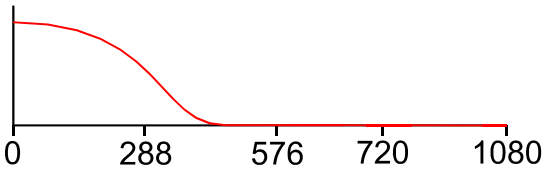


Figure 10, vertical response

2.2.4 Resolution (720-line)

At the time of testing, it was not possible to analyse single frames of P2 recording, however the visual appearance was a good intermediate between 1080 and 576. The *Detail* settings in the table are visually appropriate for film- and sport-style shooting, where the film version uses minimal boosting although there is no setting that gets satisfactorily close to a real film-look. The sport version is appropriate for news, sports, any genre other than film-look.

2.3 Noise

No calibrated noise meter was available during the measurement procedure, and the camera specification does not mention noise. Again, software analysis of frames gives some indication of performance. Measuring the signal-to-noise ratio is just one colour patch of the Macbeth chart (the white patch when slightly under-exposed, 0db *Gain*) gives a figure of 44dB. Although it is highly dangerous to use such a small number of samples for analysis, the error is known to be less than 2dB, thus noise is between 42dB and 46dB. This agrees with subjective evaluation, and explains the high value set for *Detail Coring*. At +12dB, the noise is plainly visible; even with *Detail Coring* set to +4, the noise level was sufficiently high to cause detail enhancement to switch off, resulting in visibly softened pictures. This explains the *Gain* settings of +3dB and +6dB.