Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 51 : Tests and Settings on a Panasonic AG-HMC151

This document is a report of the results of tests that are the precursor of those described in the EBU technical document Tech3335. It is not an endorsement of the product.

Data for this section is taken from the user manual and a short examination of a production model of the Panasonic AG-HMC151 camcorder. This is a HDTV unit, physically almost identical to the AJ-HPX171, with 3 ⅓" ccds, the manual gives no clue as to the sensor resolutions. The model under test ran at both 60 and 30Hz video rates (actually 59.94 and 29.97), 24Hz (actually 23.98), and 50 and 25Hz. It records HDTV using the AVC-HD algorithm (at data-rates between 6 and 21Mb/s). It does not operate in any SDTV mode. Recording is onto SDHC cards, there is no tape mechanism.

The camera is light (1.7kg) and has an integral lens and viewfinder, with side lcd panel, and seems aimed at the high-end of the consumer market rather than full broadcast, which would normally demand interchangeable lenses and higher-quality recording media and coding.

It has the usual internal menus for setting the performance, not as complex as in broadcast cameras, but enough to control most of the important features. It is not suited to multi-camera operation because it cannot be genlocked or remotely controlled. It has analogue video outputs (components via a multi-pin connector) and digits via HDMI and USB. There is a section on measurements at the end of this document.

The specification claims sensitivity to be 3 lux at F/1.6, 1/25 second shutter, and +12dB gain. This converts to approximately F/14 for 2000 lux from a reflectance chart of 90%, typical of HDTV cameras with sensor pixels of 5 μm such as are used in full-resolution HDTV cameras.

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, maybe 10.5, 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 most 2"/3 cameras.

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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" was not specifically measured, but is assumed to be the same as for the HPX171 about 640ASA. The camera and menu structure are both extremely similar to those of the HPX171.

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 are very similar to those of the HPX171 and share some features with the Varicam, in that Scene Files store a great deal of information, permitting widely different settings to be stored. When shooting in 720p mode, the camera can shoot at a variety of frame rates between 12 and 50 or 60, depending on the system speed.

BBC-preferred values are given 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 effect on picture appearance are highlighted. 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 or ARIB bars that are ubiquitous in HDTV. Factory default values, where known, are underlined.

Settings are only starting points, recommendations. They should not be used rigidly, they are starting points for further exploration. However, they do return acceptable image performance.

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
SW MODE	Configuration of switches
AUTO SW	Control of camera automatic features
RECORDING SETUP	SDHC card controls
TC/UB SETUP	Time Code and User Bits
AV OUT SETUP	Configure audio/video connections
DISPLAY SETUP	Viewfinder and LCD panel settings
CARD FUNCTIONS	P2 flash card controls
USER FILE	
META DATA	
OTHER FUNCTIONS	Sundries that don't fit anywhere else

PB MENU Playback in the camera

PLAY SETUP	
THUMBNAIL SETUP	
OPERATION	Clip management
SW MODE	
AV OUT SETUP	Analogue connection and HDMI settings
DISPLAY SETUP	Viewfinder and LCD panel settings

CARD FUNCTIONS	Formatting etc
USER FILE	
OTHER FUNCTIONS	Sundries that don't fit anywhere else

CAMERA MENU

SCENE FILE (1-6)

Item	*mode*	*range*	*comments*	*BBC*
Card Read/Write	Camera	Read, Write, No	Load, Save a scene file, SD card	
Load/Save.Init	Camera	Load, Save, Initialize, No	Load/Save scene files in the camera, Initialize=factory reset	
Synchro Scan	Camera	1/n~1/249.8	n=frame rate, will not set longer than 1/field or frame	
Detail Level	Camera	-7~0~+7	Horizontal and vertical edge detail[1]	0 (1080i) -2 (1080p) +2 (720sport) -4 (720film)
V Detail Level	Camera	-7~0~+7	Vertical edge detail	-2 (1080i) -4 (1080p) +3 (720sport) 0 (720film)
Detail Coring	Camera	-7~0~+7	Noise limiting for detail	+2[2]
Chroma Level	Camera	-7~0~+7	Saturation	0
Chroma Phase	Camera	-7~0~+7	Hue	0
Color Temp Ach	Camera	-7~0~+7	Fine white balance offset, affects A preset	
Color Temp Bch	Camera	-7~0~+7	Fine white balance offset, affects B preset	
Master Ped	Camera	-100~0~+100	Master black lift	
A. Iris Level	Camera	-10~0~+10	Auto iris gain	
DRS	Camera	Off, 1, 2, 3	Dynamic Range Stretch	
Gamma	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 (video) Cine (film)
Knee	Camera	Auto, Low, Mid, High	Reaches ~ 250%, knee at 80%,90%, 100%	90%[3]
Matrix	Camera	Norm1, Norm2, Fluo, Cine-like	Not tested in depth	Norm1/ Norm2[4]
Skin Tone Detail	Camera	On, Off	Reduces skin detail	Off
Name Edit	Camera		Names the selected scene file	
Operation Type	Camera	Video/Film	Set shutter and fps values, also sets SynchroScan indicator to time or angle	

SW MODE

Item	*mode*	*range*	*comments*	*BBC*
Mid Gain	Camera	0, 3, 6, 9, 12dB	Gain switch mid position	
High Gain	Camera	0, 3, 6, 9, 12dB	Gain switch high position	
ATW	Camera	Ach, Bch, PRST, Off	Select which switch setting to use	
Handle Zoom	Camera	L/Off/H, L/M/H, L/OFF/M	Set zoom speed switch settings	
Iris dial	Camera	Down open, Up open	Reverses iris control (when Manual)	
User 1,2,3	Camera	Spotlight, Backlight, Blackfade, Whitefade, ATW, ATWlock, Gain18dB, Dzoom, Index, ShotMark, Last Clip-	Assign user switches. 18dB works only with P formatsp. Default:1=Whitefade, 2=Backlight, 3=Index	
Focus Assist	Camera	Expanded, Graph, Both	Assign Focus Assist button, Graph shows frequency graph	
WFM	Camera	Wave, Vector, Wave/Vect	Waveform or vectorscope	
LCD	Camera	LCD rev, LCD bl	Assign LCD button. Bl is backlight	

[1] These values for detail enhancement are taken from the settings document for the HVX200, since this camera is almost identical to it. One set of values was checked, and found to produce the expected results.
[2] Noise levels are lower than in the equivalent camera, the HVX200, so coring level can be set lower, resulting in slightly sharper pictures.
[3] The knee function cannot be switched off. Although this makes some measurements difficult to make, at least it ensures that overloading will not necessarily cause clipping.
[4] Norm1 appears to be normal, Norm2 produces higher saturation, the other matrices produce special effects.

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

RECORDING SETUP					
Item	***mode***		***range***	***comments***	***BBC***
Rec Format	Camera	59.94	PH 1080/60i, PH 1080/30p, PH 1080/24p, PH 720/60p, PH 720/30p, PH 720/24p, HA 1080/60i, HG 1080/60i, HE 1080/60i	Non-standard terminology	PH 720[5]
		50	PH 1080/50i, PH 1080/25p, PH 720/50p, PH 720/25p, HA 1080/50i, HG 1080/50i, HE 1080/50i	PH=21, HA=17, HG=13, HE=6Mb/s, all VBR	
Prerec Mode	Camera		On, Off	Memory cache for prerecording	
Time Stamp	Camera		On, Off	Burns in time/date	
Mic ALC	Camera		On, Off	Auto level control	
Mic Gain 1	Camera		-50dB, -60dB	External mic level control	
Mic Gain 2	Camera		-50dB, -60dB	External mic level control	

AV OUT SETUP				
Item	***mode***	***range***	***comments***	***BBC***
HDMI Out Sel	Cam/PB	Auto, Fix, 576p/480p	Set output of HDDI	
Cmpnt Out Sel	Cam/PB	Auto, 1080i, 576/480i	Set output of analogue	
Downcon Mode	Cam/PB	Side crop, Letter box, Squeeze	Usual stuff	
Video Setup	Cam/PB	0, 7.5%	Video black level, for 60Hz only	
Audio Out	Cam/PB	Ch1/Ch2, Ch1, Ch2		
HP Mode	Camera	Live, Recording	Headphone feed, use Live for off-speed	

DISPLAY SETUP				
Item	***mode***	***range***	***comments***	***BBC***
Zebra Detect 1	Camera	50%~105% by 5%	Default 80%, left-leaning zebra	
Zebra Detect 2	Camera	50%~105% by 5%, Off	Default 100%, right-leaning zebra	
Marker	Camera	On, Off	Press Zebra button to display markers	
Safety Zone	Camera	90%, 4:3, Off		
Rec Counter	Camera	Total, Clip	Record counter	
Video Out OSD	Cam/PB	On, Off	Screen info to video output	
Date/Time	Cam/PB	Off, Time, Date, Time&Date	What to show on screen	
Level Meter	Cam/PB	On, Off	Audio levels on screen	
Zoom, Focus	Camera	Off, Number		
Card/Batt	Cam/PB	On, Off	Remaining capacity	
Other Display	Cam/PB	Partial, All, Off	Amount of stuff shown in the V/F	
LCD backlight	Cam/PB	High, Normal, Low	Brightness	
LCD set	Cam/PB	LCD color level, LCD brightness, LCD contrast	Panel, set brightness, contrast, colour	
EVF set	Cam/PB	LCD color level, LCD brightness, LCD contrast	V/F, set brightness, contrast, colour	
Self shoot	Camera	Normal, Mirror	For when panel is forward-facing	
EVF color	Cam/PB	On, Off	For black/white V/F	

CARD FUNCTIONS				
Item	***mode***	***range***	***comments***	***BBC***
Card Format	Cam/PB	Yes, No	Format the SD card	
Card Status	Pam/PB	Yes, No	Shows SD card status	
Clip Property	PB	Yes, No	Show info on selected clip	

[5] The camera does not produce significant content above the limits of 720p, therefore it makes more sense to shoot only 720p since it can be better down-converted to SD than 1080i.

USER FILE				
Item	***mode***	***range***	***comments***	***BBC***
Card Read/Write	Cam/PB	Read, Write, No	Up to 4 User files	
Load/Save/Init	Cam/PB	Load, Save, Initialize, No	Power on/off needed to take effect	

META DATA				
Item	***mode***	***range***	***comments***	***BBC***
Card Read	Camera	Yes, No	Load from SD card	
Record	Camera	On, Off	Save meta data with video	
User Clip Name	Camera	Type1, Type2		
Clip Count Reset	Camera	Yes, No		
Meta Data Prop	Camera	Yes, No	Show meta data	
Meta Initial Set	Camera	Yes, No	Initialize meta data	

PLAY SETUP				
Item	***mode***		***range***	***comments***	***BBC***
PB Format	PB	50	1080/50i (25p), 720/50p (25p)	Playout	
		59.94	1080/60i (30p), 1080/24p, 720/60p (30P), 720/24p		
Repeat Play	PB		On, Off	Clip looping	
Resume Play	PB		On, Off	Start playout from where left off	
Skip Mode	PB		Clip, Clip&Index	Start point for play after pause	

THUMBNAIL SETUP				
Item	***mode***	***range***	***comments***	***BBC***
Thumbnail Mode	PB	All, Same Format, Marker, Index		
Indicator	PB	On, Off		
Data Display	PB	TC, UB, Time, Date, Date&Time		
Date Format	PB	Y-M-D, M-D-Y, D-M-Y		

OPERATION				
Item	***mode***	***range***	***comments***	***BBC***
Delete	PB	All Clips, Select, No	Won't delete protected clips	
Index	PB	Yes, No	Add indices to clips or delete them	
Clip Protect	PB	Yes, No	Protect clips	

OTHER FUNCTIONS				
Item	***mode***	***range***	***comments***	***BBC***
IR Remote	Cam/PB	On, Off		
Rec Lamp	Camera	Front, Rear, Both, Off		
Beep Sound	Camera	On, Off		
Clock Set	Cam/PB			
Time Zone	Cam/PB	-12~0~+13	Set in hours relative to GMT	
Power Save	Camera	On, Off	About 5 minutes, except when on external power or PB mode or no SD card inserted	
System Freq	Camera	59.9, 50	Default frame rate is for E model	
System Info	Cam/PB		Camera version number	
Menu Init	Camera		Reset all menu items (not time zone)	
Operation Time	Cam/PB		Show poer-on time	

2 Measurement results

The HMC151 has no built-in test signal generator. This alone sets it apart from most professional and broadcast cameras. Thus measurements of the gamma curve are difficult, using optical test cards and an awful lot of data processing.

2.1 Transfer characteristic (gamma-correction)

By inspection, the available gamma curves seem to be identical to those of the HVX200, and HPX171, therefore, specific measurements were not made on this camera and the results for the HVX200 are quoted here, except for the overexposure range, which was confirmed as 250%.

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 an exposure limit of 2.5 (250%) before clipping occurs at about 107%.

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

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

The contrast range for the settings given in this document are derived from these 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 ARIB colour bars, used for setting display black level). Since the noise level is reasonably low, a lower point can be taken, 1% would be the normal minimum considered relevant here. For the *Hdnorm* curve, this defines the contrast capture range to be about 1100:1 (10.1 stops), quite good for a camera in this category. Measurements of the High (Black Stretched) gamma-correction curve produced a decent match to the BBC 0.4 law:

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

This gamma-correction curve generally produces more accurate colour rendering.

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.

2.2 Resolution and Detail

The HMC151 is interesting in that the sensors do not appear to be native-resolution for HDTV. Although the specification does not say so, the 3 ccds are each 960 by 540 pixels spaced on a 5µm grid as in full-resolution ⅔" 1920x1080 sensors; it would be more usual to find sensors, in a 1080-line camera, having 1080 lines rather than only 540 but that would be at the expense of either sensitivity or video noise. Presumably, 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). In most cameras with less-than-ideal numbers of pixels, the camera is made to deliver 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) at the expense of introducing some coloured aliasing, similar to that from a Bayer-patterned single sensor. This is particularly relevant since the camera delivers signals at 1080 and 720. Although this camera does have quincunx precision offset, there is only faint evidence of the diagonal aliases it inevitably produces, either the lens is a little soft, or the camera has good bi-refirngent optical filtering, or both.

A zone plate test chart was used, calibrated for 1920x1080 HDTV. It contains 6 circular patterns, each being a phase space of the spatial-frequencies (i.e. all possible frequencies in all possible directions) which such a camera should resolve. Analysis was made of one zone (in luma, or grey scale) to investigate the frequency responses and the presence of aliases.

2.2.1 Detail enhancement

The settings for the HVX200 and HPX171 were used here, since there seemed to be no good reason for changing them. Although this setting produces a little overshooting on edges (there was no setting in the HVX200 at which the overshoots were absent), *Detail level* settings of *0* and *-2* (horizontal and vertical) are still recommended, but the coring level can be lowered since the noise performance is rather good (see section 2.3, below).

2.2.2 Resolution (1080-line)

This is a quarter of one circular zone plate from the test chart, 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 (where the concentric circles are reversed, taking centres outside the pattern), 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.

Figure 1 Resolution 1080-line

The absence of coloured aliasing could be interpreted as evidence to support the supposition that there is no precision-offset of the sensors, and why there is no extension of the frequency response beyond 960x540. However, the aliasing is not particularly strong, which indicates that there is either a good optical low-pass filtering (bi-refringent) or that the lens is relatively soft. The diagonal aliasing is strong evidence that quincunx precision offset is used.

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

2.2.3 Resolution (720-line)

Resolution at 720-line is almost identical to that at 1080-line. This is a good indication that it would be better to shoot at 720p, since then 50Hz images can be recorded, which are much easier to down-convert to SDTV using relatively simple conversion.

2.2.4 Lens aberrations

The lens showed a little chromatic aberration in the corners. In this example, there a displacement of

Figure 3 Chromatic aberration

between 2 and 3 pixels. Thus is quite adequate for a consumer/professional HD camera, and does not present any problem.

2.3 Noise and Sensitivity

No calibrated noise meter was available during the measurement procedure, and the camera specification does not mention noise. Software analysis of captured frames gave some indication of performance. Measuring the signal-to-noise ratio at several signal levels, all at 0dB gain, produced noise levels from -48 to -52dB. This is quite good for any HDTV camera, a performance achieved by the use of sensors with large photosites. This was confirmed by direct observation on the crt display and waveform monitor.

However, the noise level is normally expected to change with signal level, since it is primarily caused by the sensors and head amplifiers (before gamma correction) and thus should correlate with the slope of the gamma curve, typically by 10dB or more (noisier near black). There was no evidence of such a noise distribution.

One possible cause could be the use of head amplifiers with a limited gain-bandwidth product, this would produce softer pictures at low signal levels, and reduce the noise near black. It is very difficult to measure resolution at low signal levels, so it is almost impossible to establish whether this trick has been played. If it has, it has worked.

Another possible cause could be that the primary source of noise in this camera is the digital coding system rather than the sensors and heads amplifiers themselves. The performance measured is typical of 10-bit data in the linear signals, or 8-bits after gamma correction. AVCHD is an 8-bit recording system, so has a noise floor of about -54dB, so the measurements are all realistic.

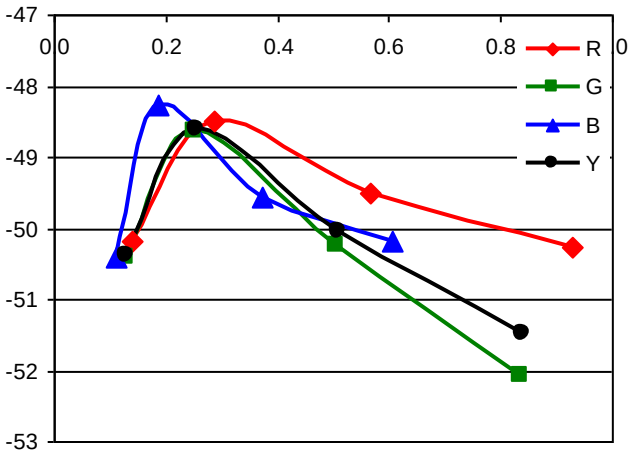

Figure 4 Noise levels

Sensitivity was not measured. However, the specification claims 3 lux at F/1.6, +12dB gain, and 1/25 second shutter. Thus, sensitivity is 6 lux at F/1.6, +12dB gain and 1/50 second shutter, 24 lux at F/1.6 and 0dB gain and 1/50 shutter. The aperture setting for 2000 lux illumination is thus $1.6\sqrt{2000/24} = 14.6$, which is typical for cameras with 2”/3, full-resolution sensors, which have pixels of the same dimensions as the half-resolution sensors in this camera.