EBU

OPERATING EUROVISION AND EURORADIO

TECH 3335

METHODS OF MEASURING THE IMAGING PERFORMANCE OF TELEVISION CAMERAS FOR THE PURPOSES OF CHARACTER -ISATION AND SETTING

SOURCE: FT-V

Geneva
August 2014

* Page intentionally left blank. This document is paginated for two sided printing

Contents

Acknowledgement

Although this document is a team effort, the EBU gratefully acknowledges the expertise contributed by Alan Roberts in crafting this publication.

Methods for the Measurement of the imaging performance of Television Cameras for the purposes of Characterisation and Setting

EBU Committee	First Issued	Revised	Re-issued
FT-V	01/2012	08/2014	

Keywords: Imaging Performance, TV Camera, Setting and Characterisation.

Introduction

This document describes measurement procedures for assessing the quality of video cameras used in television production.

These procedures do not supplant existing EBU procedures EBU Tech 3281, EBU Tech 3281 Supplement 1 and EBU Tech 3294 for acceptance testing however, some may be used to supplement acceptance testing as well as establish the best settings for a cameras use in a variety of programme-types.

The results of these tests greatly simplify the derivation of optimum settings for a camera which involves as much art as it does science, since it defines the 'look' that the camera will deliver.

Although it may not be necessary to perform a full set of tests on a camera if a visual inspection of the picture performance does not reveal anything suspicious - whether unusually good or unusually bad. A full test is normally recommended for confidence and is essential when settings are required to deliver a specific 'look' for a programme or programme type.

It is *essential* the full test be carried out for the purpose of applying a camera Tier as defined in EBU R 118. A full written report must be published to accompany any tiering decision made about a camera.

To carry out a full test the following performance parameters will be measured;

- Electro-optic transfer function (gamma curve)
- Noise levels and noise distribution
- Sensitivity
- Exposure range, including the effects of black stretch/press and knee
- Colour rendering
- Infra-red response
- Spatial resolution, detail settings and aliasing
- Lens/optical aberrations
- Temporal/shutter effects

The techniques described in this document can be applied equally to broadcast and consumer cameras, with 4:3 or 16:9 aspect ratios, and operating at SD or HD scanning standards. Nothing in these tests is specific to any one type of camera.

No test carries any risk of damage to the camera, or to the tester.

1. Procedures

1.1 Precautions

The camera should be mounted on a suitable tripod or other camera mounting, such that it can be trained on the test cards. Test cards can be front lit using two luminaires to ensure reasonably uniform illumination. Shading is not a problem as it can be corrected as part of the measurement procedure. Special illumination is required for some tests, particularly when assessing colour rendering.

Measurements can be made in two ways, subjective and/or analytical.

- Subjective assessment can be rapid and will always reveal whether analytical measurements are needed. They can be used as a confirmation of results and to demonstrate any effects.
- Analytical measurement takes considerably longer, and requires special equipment and/or software analysis.

In all cases, the camera must be white balanced to the illuminant used for the tests, and also black balanced where black balance controls are available.

Test cards

Most testing can be accomplished with only two test cards.

Exposure test card: a simple white and grey combination, with reliably known reflectance. The Kodak cards are ideal for this, although a ColorChecker® chart is also suitable.

Colour test card: this should have a good variety of test colours. A photograph is not good enough, nor is a test chart specialising in only a few colours (e.g. skin tones). The photographic industry has long used the ColorChecker® chart (Figure 1) for colour testing.

Figure 1: ColorChecker® chart

Although this is a photographic test card, it can also be used for testing television cameras. It comprises an array of 24 patches in four rows of six with calibration data available for each colour.

From this information it is possible to calculate the signal voltages a camera should produce for each patch, and therefore it can be used both for subjective and analytical testing.

Only genuine ColorChecker® charts should be used; poor copies should be avoided. The authentic ColorChecker® chart has been manufactured by several companies, originally by Macbeth (then a division of Kollmorgen) and now by X-rite (a part of Munsell Color), and it is obtainable through many television and film hire companies.

Resolution test chart: many charts are available, some for home printing, but few contain sufficient patterns for proper testing. Only a zone plate test chart contains sufficiently critical patterns for full testing of a camera. The zone plate patterns can be circular or hyperbolic however circular patterns are far easier to use. The modulation must be sinusoidal rather than the much simpler square wave. A suitable range of zone plate test charts is available from Broadcast Production Research.

The example shown below (Figure 2) was calculated for wide-screen SDTV (576-line). Separate test charts are required for each camera resolution, specifically calculated to fill the system resolution.

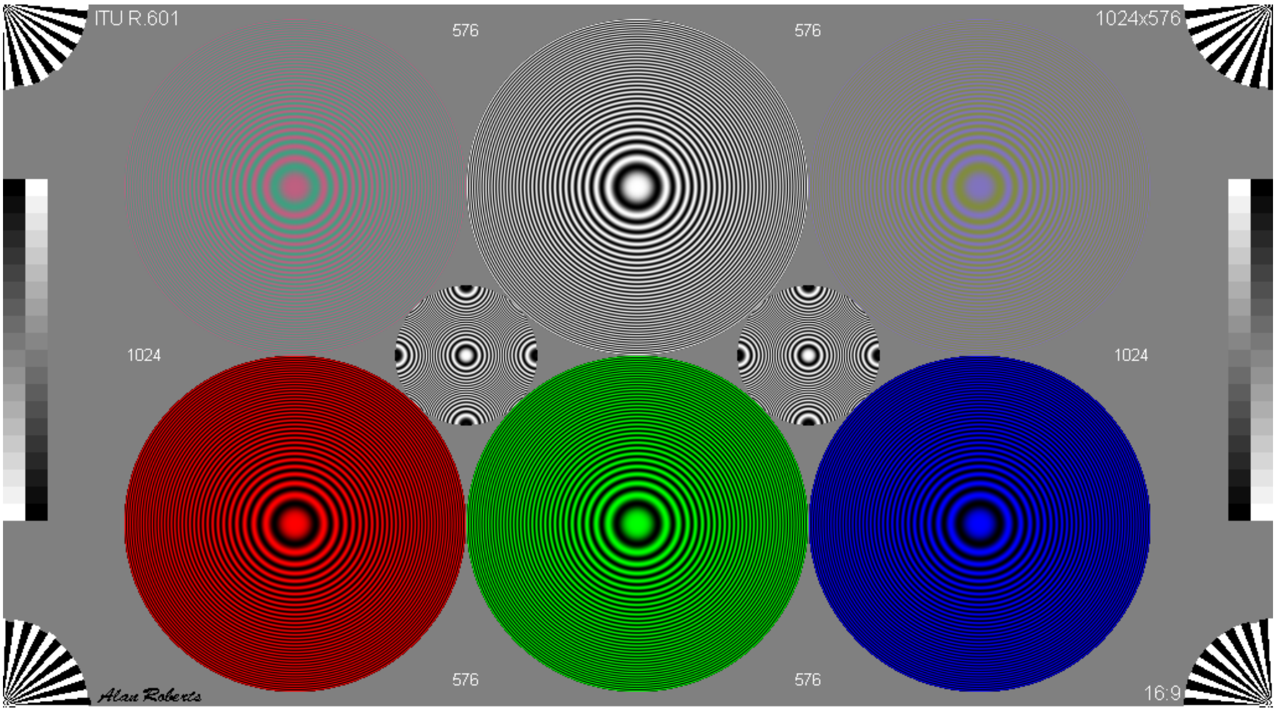


Figure 2: Example of a resolution test chart

Exposure range measurement: specialist equipment for the direct measurement of exposure range, including software, is available from ARRI Media.

Lens test chart: specialist lens test charts are not required for these tests. The recommended zone plate test chart contains sufficiently challenging patterns that should reveal any serious lens defects. If further lens testing is required, for example, analysis of the Modulation Transfer characteristics (MTF), the lens will have to be tested in isolation in a specialised optical test bench. Such procedures for HDTV lenses are under development by the EBU.

Test equipment

Picture monitor: broadcast-quality television picture monitor, conforming to the latest version of EBU Tech 3320, set up and viewed in accordance with ITU-R BT.500. Connection to the display should be made using the highest quality output from the camera (e.g. SDI/HDSDI).

Waveform monitor: broadcast-quality waveform monitor connected via the same high quality feed as the picture monitor and set to the camera's line and field/frame-scanning standard. In practice, a waveform monitor may not be essential if software analysis of captured images is available. Some cameras have such monitoring in the viewfinder and this may be acceptable if the resolution and calibration are adequate for reliable measurements to be made. Software waveform-monitoring solutions are also available (e.g. Black Magic Ultrascope).

Image capture: it is advisable to be able to capture images from the camera for measurements and to record the performance of the camera. The recorder should use the same digital feed as the picture and/or waveform monitor Capture should be uncompressed SDI/HDSDI, so specialist equipment may be needed. If the camera does not have a digital output (HDMI is acceptable provided the data-stream is uncompressed), its analogue feed can be converted to serial digits for capture, using a suitable converter. Results will be less reliable since the camera will not normally be used in this way. When camcorders with no digital output are tested, only the recorded signal need be captured. Analysis of captured images requires specialised software, which is described later in this document.

Arri Media exposure test: equipment for this test is available from Arri Media. It comprises a rear-illuminated fully-opaque test card containing many small apertures. Each aperture contains a transparency, modulated with a single spatial frequency and at a range of mean transmittances from near white to near black. A video capture and software analysis system from Arri Media, performs all the measurements and calculations.

Light meter: a calibrated illuminance meter. Ideally, this should carry calibration data traceable to a national standards body. It should be calibrated in lumens/square metre (lux).

Rotary motion: a multi-bladed fan, capable of rotating at variable and controllable speed. The speed of rotation must have sufficient range to cause problems with 'rolling shutter' sensors. If the fan has *b* blades, then it must be capable of being set to 3000/*b* rpm, so that one blade will travel up or down the picture in one field (for 50 Hz, 'PAL' cameras) or to 3600/*b* rpm for 59.94 Hz, 'NTSC' cameras. Ideally, the speed should be continuously adjustable. A small fan, specifically modified for these tests is available from Broadcast Production Research.

2. Measurements

As there are two possible methods of testing for each measurement (visual and analytical), both methods will be given, where relevant.

2.1. Opto-Electronic transfer curve (Gamma)

If it is possible to inject a linear saw-tooth into the camera, and a waveform monitor is available, this measurement is relatively straightforward. It is still possible to achieve it by software analysis, but this is a long process.

Tech note: All black stretch/press and knee options must be turned off for this measurement.

2.1.1 Visual method – saw-tooth

It is not possible to make an accurate measurement of the transfer curve by purely visual means. It is, however, usually possible to determine a camera's gamma curve, from a list of possibile options.

- Set the waveform monitor to line-scan.
- Set the scan position to nominal scale points such that reliable measurements can be taken, both of signal level, and horizontal position along the saw-tooth.
- Find the horizontal position for 20% of the nominal full saw-tooth scan, and then read the video signal level at the input level.

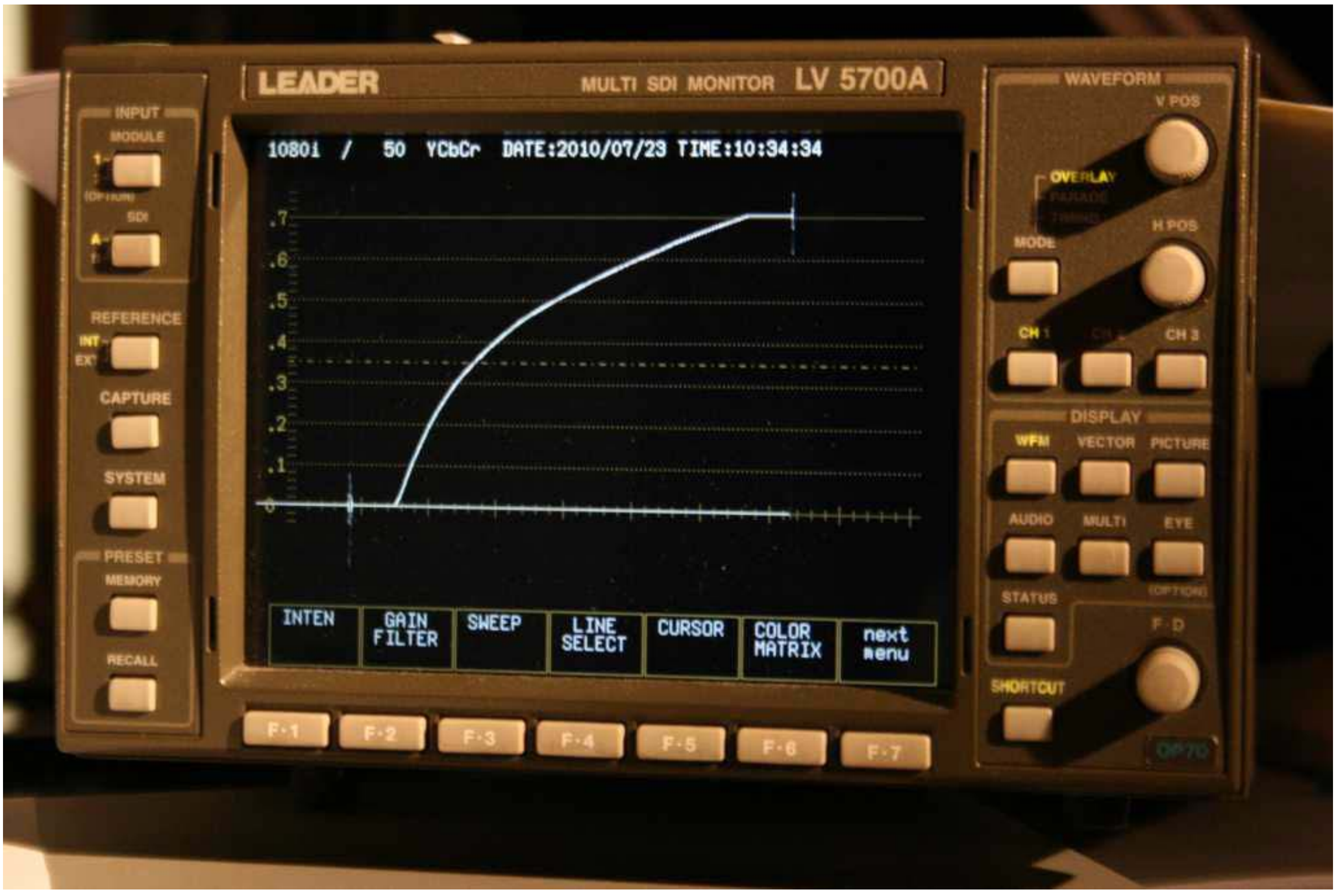


Figure 3: Saw-tooth

This determines three points on the gamma curve, black, 20% input, and white.

Annex 3 lists several standard gamma curves, and some logical extensions to that list, giving the equations and the signal value at 20% and 50% input. Find the curve that most closely matches the 20% value. If there is no close match, then further (analytical) analysis is needed.

2.1.2 Visual method - test card

- Set up two Kodak Gray cards, overlapping and evenly lit. One card should show the 18% reflectance side (grey), the other the 90% (white) side.
- Set the waveform monitor to line-scan and adjust the camera exposure to set the white card to produce 100% signal level.
- Measure the signal level from the grey card, this is the 20% input (exposure) level.

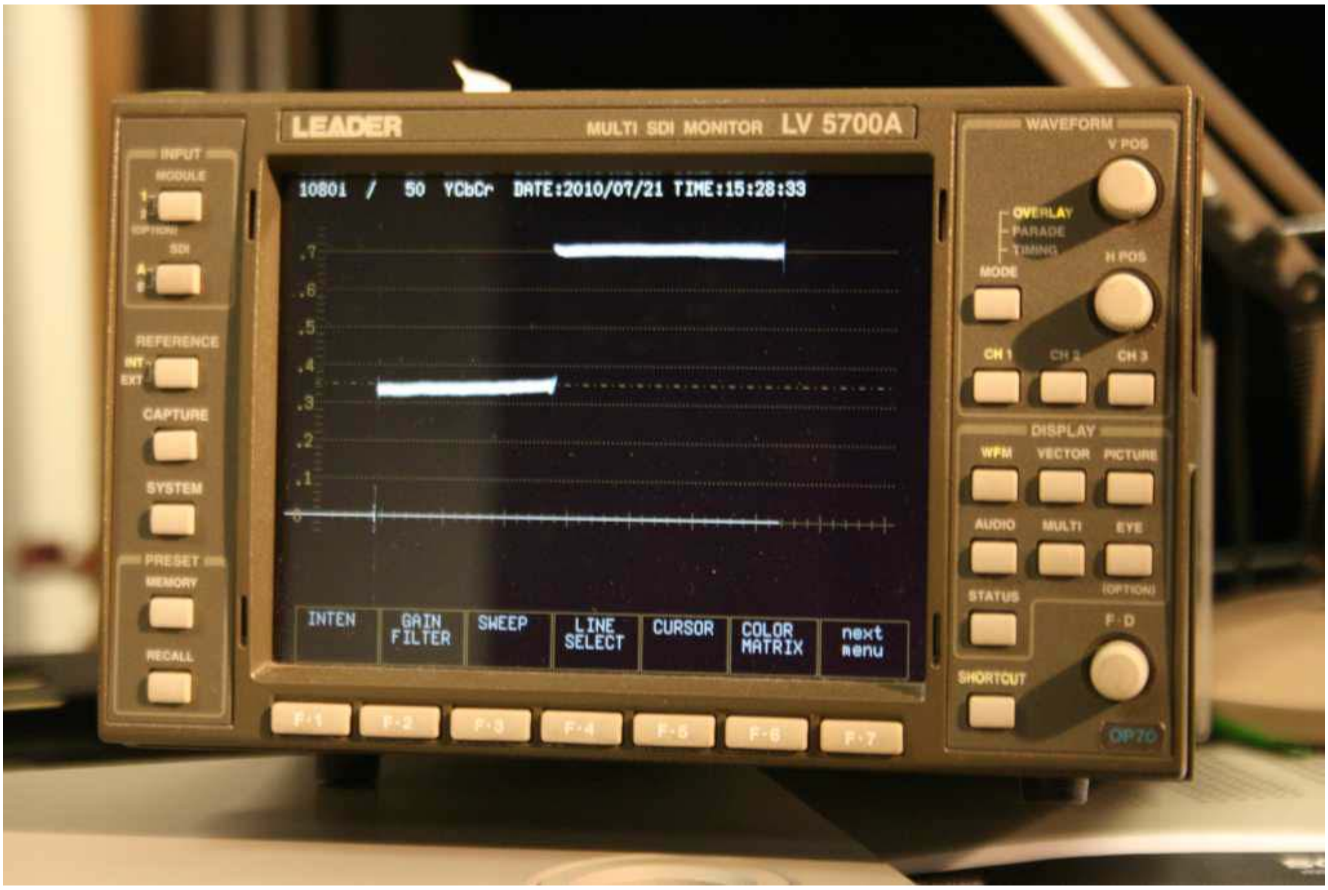


Figure 4: Kodak Grey

Then determine which gamma curve most closely matches the value as described above.

2.1.3 Analytical method – saw-tooth

- Capture one video field or frame containing the saw-tooth test signal Lens/opt.
- Extract a single line of video from that image, and save it as a series of signal values for import into a spreadsheet (e.g. a text file).
- Import that data into a spreadsheet, for use as a set of Y' values.
- Calculate a linear set of values, incrementing by 1, to form a set of samples or 'exposure values' for the Y' values.
- Generate a line plot of these values to show the saw-tooth signal, plotting Y' versus exposure.

Figure 5: Frame containing a saw-tooth signal

The curve will not start at the first sample and therefore the tester must estimate at which sample the curve actually starts. In the example given, the curve starts (i.e. departs from black) at sample number 103 and reaches white at sample number 922. A new horizontal axis can be calculated from the sample numbers, such that the curve starts from a zero value and ends at a unity value, although this is not strictly necessary if horizontal offset and scaling are taken into account in the calculations.

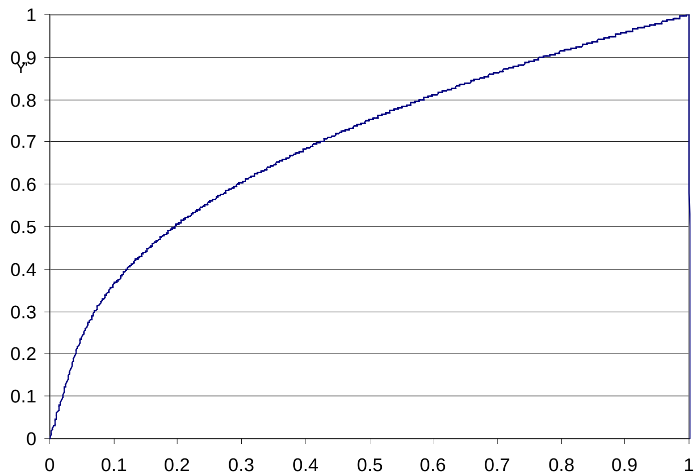


Figure 6: Opto-electronic transfer characteristic

Simulated example data		
Sample number	Exposure	Signal
3	0	0
4	0	0
5	0	0
...	...	...
103	0	0
104	0.001221001	0.008
105	0.002442002	0.012
106	0.003663004	0.020
107	0.004884005	0.024
...		
916	0.992673993	0.996
917	0.993894994	0.996
918	0.995115995	0.996
919	0.996336996	1
920	0.997557998	1
921	0.998778999	1
922	1	1
923	1.001221001	1
924	1.002442002	1
...		

Using these sample values, form another set of video sample values, calculated using one of the standard gamma curve equations. If this curve is plotted together with the measured camera curve over the same range of samples, it is possible to estimate which gamma curve has been used in the camera. The curve can be plotted with linear or logarithmic axes. Should the curve not fit well, it is quite easy to derive a curve that does fit the data by manually adjusting the coefficients.

2.1.4 Analytical method - test card

- Set up a ColorChecker® test card, evenly illuminated. If the illumination cannot be made even, record one exposure of the camera to the white side of a Kodak Gray card, for use as a reference in the calculations It is not necessary to be precise in exposure measurements for this test.

- With the ColorChecker® card in view, record an image such that the white patch (bottom left) produces peak white. It does not matter if the white is slightly clipped, the calculations will allow for that. Note the lens aperture setting, although it is not necessary to be precise in exposure measurements for this test.
- Record a series of exposures, with the lens closed down by one or two stops at a time, until the lowest reflectance patches in the grey scale are indistinct.
- Capture each of these images into suitable software, and export Y' values for each patch of the grey scale, at each captured exposure level. These values, together with the known reflectance of the patches (see **Annex 2**) and the estimated exposure levels, form a data set exploring the gamma curve. Analysis is inevitably tedious and time-consuming, since a degree of human involvement is essential.
- Import these values into a spreadsheet as Y' values, and estimate relative exposure values based on the numerical data for the chart and the approximate exposure levels.
- Plot the results as a graph.

Each exposure produces 6 points on the gamma curve, and the relative exposure values can be estimated such that the Y' points for each exposure fall onto a single curve rather than a set of similar curves. Once a single curve has been derived, a matching curve can be calculated as above (§ 2.1.3).

The data values in the table below are those for four measurements of a consumer camcorder. For each 'Take', the luma channel for the colour patch is entered in the column marked Y'. The left-hand column for each 'Take' is the estimated exposure value for that patch, being the patch reflectance value multiplied by the estimation of the relative exposure, shown in red.

Table 1: Example gamma measurement result representation for different exposure (Take) of the test card.

Reflectance		Take 1	Take 2		Take 3		Take 4	
		Y'	**0.39**	**Y'**	**0.28**	**Y'**	**0.085**	**Y'**
White	0.9001	0.753	0.3510	0.504	0.2520	0.441	0.0765	0.268
Neutral 8	0.5910	0.631	0.2305	0.425	0.1655	0.372	0.0502	0.238
Neutral 6.5	0.3620	0.520	0.1412	0.341	0.1014	0.306	0.0308	0.203
Neutral 5	0.1977	0.384	0.0771	0.269	0.0554	0.243	0.0168	0.155
Neutral 3.5	0.0900	0.284	0.0351	0.209	0.0252	0.182	0.0076	0.118
Black	0.0313	0.189	0.0122	0.128	0.0088	0.115	0.0027	0.096

This method is subject to noise disturbance, and it is therefore not wholly reliable, but in cameras without saw-tooth test signals, it is the best that can be done.

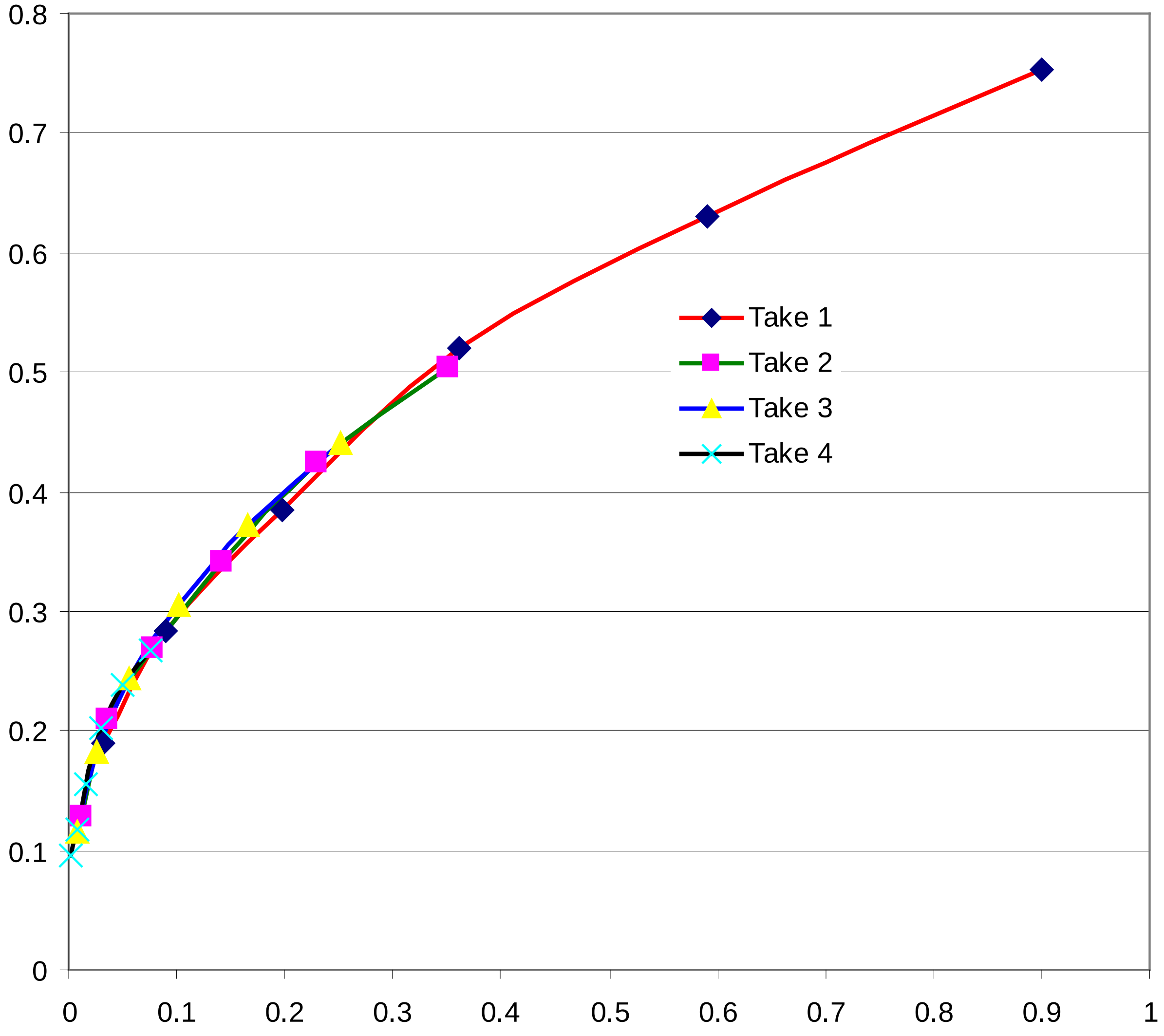


Figure 7: Gamma analysis of a consumer camcorder

2.2 Noise levels and noise distribution

Initial visual inspection of camera pictures should establish whether noise measurements are required. In general, the larger the camera image format, the lower the noise level. Noise measurement is a good way of establishing the maximum camera gain that is acceptable, and can reveal some of the secrets of the camera design.

Ideally measurements should be made with the camera set to 0 dB gain, so that results can be compared with the manufacturers' claims. However, it may be more convenient to raise the camera gain by 6 or 12 dB, in order to make the measurements more certain, provided due allowance is made in the calculations for the offset.

Noise distribution measurements can reveal the workings of the gamma correction (hinting at whether it is done in the digital domain or in the analogue domain before the camera's ADC processing) and of any noise reduction processes.

2.2.1 Visual method - noise level

- Set up an evenly illuminated white card; either a Kodak Gray card (white side) or the reverse of a zone plate chart if it is mounted on white.
- Defocus the camera so that any blemishes are softened rather than sharply defined. Evenness of illumination is critical here. The waveform monitor can be set to field or frame scan as an aid to achieving full evenness.
- If the camera gamma curve can be switched off, do this and set the exposure to produce approximately 28% signal level. If the camera gamma curve cannot be switched off, set the exposure level so that it produces about 50% signal level (this is the signal level that, typically, implies unity-gain in the gamma correction for the ITU-R Recommendation BT.709 curve. Unity-gain values for other curves are given in **Annex 3**).
- Set the waveform monitor to line scan, and the brightness fairly high.
- Measure the peak-to-peak excursion of the noise envelope, V_{noise}.

The peak-signal-to-noise-ratio (PNSR) can then be estimated:

$$PSNR = 20\log\left(\frac{V_{noise}}{V_{peak}}\right) - 17dB$$

Where V_{peak} is 700 mV or 100%, depending on the scaling used for the noise measurement. The value of 17 dB is an approximate expression of the ratio of the peak-to-peak value of a random noise signal, relative to its mean value.

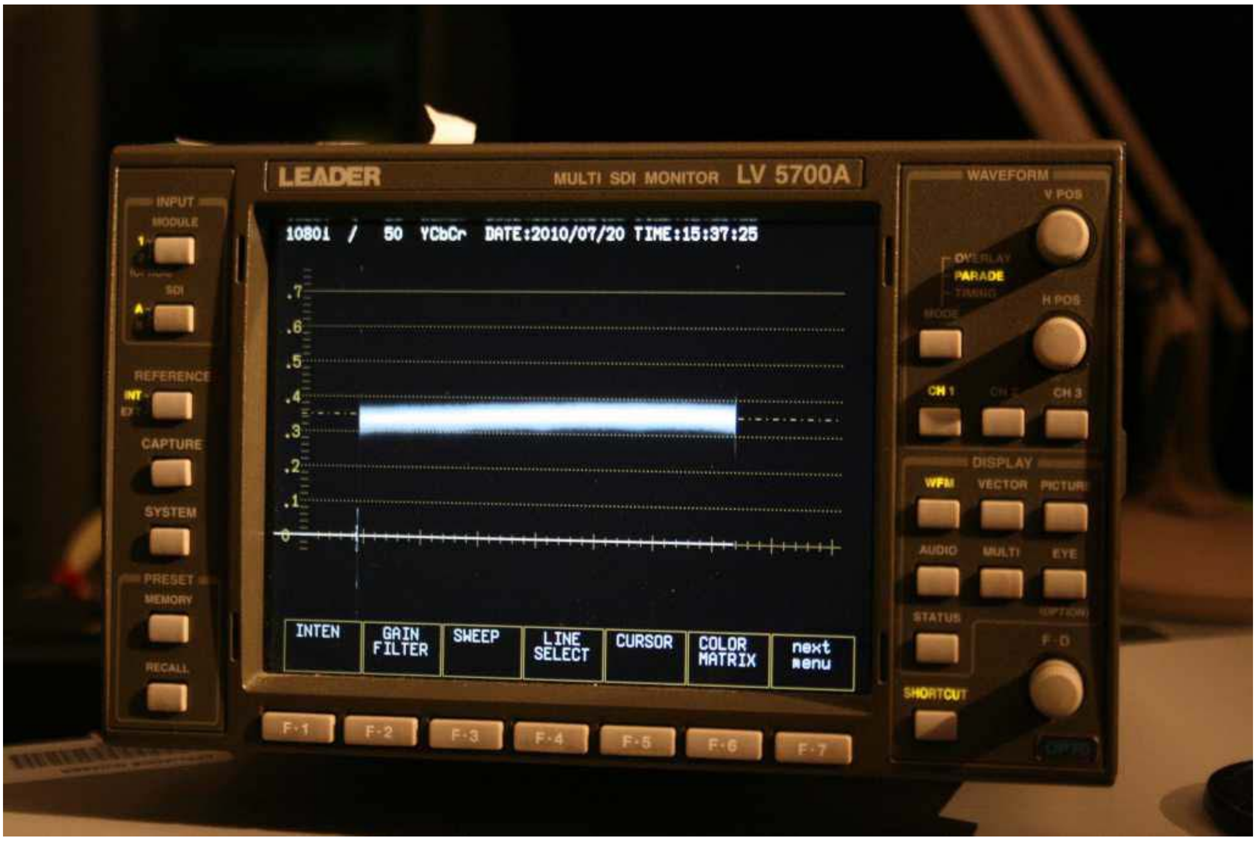


Figure 8: Flat Field

2.2.2 Analytical method - noise level

- Set up a white card, evenly illuminated, with the camera defocused, and capture an image with exposure set to approximately 50% signal level (or 28% or equivalent if the gamma curve cannot be switched off). Capture a field or frame from the video signal and import it into specialised software
- Perform a high-pass frequency filtering operation on the video data to remove the effects of any illumination shading. The filter should add an offset so that the result is not centred on zero, which could clip the noise and affect the measurements. Extra gain may also be used here, to ensure that the filtering operation loses no information, but any extra gain must be allowed for in the final calculation. Coefficients for a suitable filter are given in **Annex 4**

As an alternative to filtering, the difference between two successive fields or frames can be used, provided it is known for certain that there is no change to the illumination between the recorded images.

- Next calculate the mean signal level by summation:

$$V_{mean} = \frac{1}{hv} \sum_{x=1,y=1}^{x=h,y=v} V_{x,y}$$

Where *h* and *v* are the image dimensions in pixels and lines. In practice it is a good idea to measure a subset of the image dimensions, to eliminate the effects of filtering near the edge of the image.

- Measure the difference between each pixel value and the mean, forming a root-mean-square summation:

$$V_{rms} = \sqrt{\frac{\sum_{x=1,\ y=1}^{x=h,\ y=v} \left(V_{x,y} - V_{mean}\right)^2}{hv}}$$

The PSNR can then be calculated:

$$PSNR = 20\log\left(\frac{V_{rms}}{V_{peak}}\right) dB$$

Where V_{peak} is 700 mV or 100%, depending on the scaling used for the noise measurement.

2.2.3 Visual method - noise distribution

- Set up a ColorChecker®chart, evenly illuminated, and view the image on a waveform monitor. The image must be focussed so that each patch is clearly distinguishable.
- Expose the camera such that the white patch produces peak white, or near peak white. Ensure that the exposure setting does not clip the noise envelope either at white or black.
- For each of the six patches in the grey scale across the bottom of the chart, make a visual noise measurement using the process described in § 2.2.1.

This will produce a noise distribution profile for luminance.

2.2.4 Analytical method - noise distribution

- Set up a white card, evenly illuminated, to fill the camera image. Defocus the camera to soften any blemishes.
- Capture images at several exposure levels, using the lens iris as exposure control. Typically

4 to 6 exposures are adequate. Make sure that exposures at extreme levels do not clip the noise, or the results will not be accurate.

- Perform the analysis described in § 2.2.2 for each exposure separately. Although not essential, it is a good idea to measure the noise level in each of the R'G'B' channels as well as the luma Y' channel.

Care must be taken to ensure that the correct decoding equations are used for the video signals, those of ITU-R Rec. BT.709 for HDTV, those of ITU-R Rec. BT.601 for SDTV. Noise can also be measured in the chroma channels if necessary.

2.3 Sensitivity

Sensitivity cannot be measured visually, but analytical processes are not needed either.

Sensitivity is normally expressed in one of two ways:

Broadcast/Professional cameras: the lens transmission number (T/) at which the camera makes peak white from a 90% reflectance card, lit at 2000 lux, when the camera has 0 dB gain and a normal gamma curve without knee (or with the gamma switched off).

Consumer/'Pro-sumer' cameras: the illumination level which produces a peak white signal from a 90% reflectance card, when the lens is at maximum aperture, maximum gain, and possibly longest shutter exposure.

The two methods are linearly related and it is possible to derive each from the other.

- Set up a Kodak Gray card, white side to the camera, evenly illuminated, and defocus the camera to spread any blemishes in the card. Alternatively, a ColorChecker® chard can be used since the white patch has a reflectance almost identical to that of the Kodak Gray card, white side.
- With the camera set to 0 dB gain and standard shutter period, set the exposure such that the signal level is 100% (peak white).
- Note the lens aperture setting, and measure the illumination in lux as L100%.

The sensitivity can be calculated:

$$F/_{2000} = F/_{100\%}\sqrt{\frac{2000}{L_{100\%}}}$$

Where F/2000 is the lens aperture at 2000 Lux illumination and L/100% is the illumination at peal white.

Strictly, lens T/ numbers should be used, but these can rarely be derived except in lenses designed for cinema film shooting, so the F/ number is the best that can be derived.

This measure can be derived from the minimum illumination figure by deriving compensations for each parameter which affects sensitivity:

If the shutter is not nominal (e.g. 1/50 for 50 Hz cameras):

$$N_{shutter} = \frac{1/50}{1/n} = \frac{n}{50} \text{ otherwise } \qquad N_{shutter} = 1$$

Where *n* is the actual shutter period expressed as 1/*n*.

If the gain is not nominal (0 dB):

$$N_{gain} = 10^{20/gain} \quad \text{otherwise} \quad N_{gain} = 1$$

Where *gain* is the actual gain setting in dB.

Then the 2000 lux aperture is given by:

$$F/_{2000} = F/_{100\%}\sqrt{\frac{2000}{L_{100\%}.N_{shutter}.N_{gain}}}$$

The minimum illumination figure can also be derived from the 2000 lux aperture:

$$L_{\min} = \frac{2000}{(F_{2000}/F_{\max})^2.N_{shutter}.N_{gain}}$$

Where F_{max} is the maximum lens aperture number.

Occasionally, it is impossible to achieve 100% signal level in a camera, particularly when it has some form of 'Log' transfer characteristic intended to mimic film performance. In this case, the lens T/ number (or F/ if T/ is not available) should be found at which exactly 50% signal level occurs, again with 2000 lux illumination of a 90% grey card. This exposure level is typically 2 stops below peak exposure for a conventional gamma curve, so cameras can be related to each other through this measurement.

2.4 Exposure range

There are two separate parameters which define the exposure range of a camera: the maximum exposure level (L_{max}) to which the sensors still deliver a signal which can be dealt with by the gamma curve, and the noise level which defines the minimum exposure level (L_{min}). The exposure range is then simply:

$$ExposureRange = L_{\max}/L_{\min}$$

Which can be expressed either as a ratio (*ExposureRange*: 1) or in photographic stops:

$$Stops = \sqrt{ExposureRange}$$

The maximum exposure to which the camera still accurately responds is normally regarded as overexposure, since cameras normally do not use the full dynamic range of the sensors. This 'headroom' varies in cameras between about 1 stop and 3 stops.

2.4.1 Visual method

This measurement process works only in cameras where there is considerable control of the transfer characteristic.

- Set up a ColorChecker®chart, evenly illuminated.
- Set the camera gamma to either ITU-R Rec. BT.709 or to the BBC 0.4 law, whichever is preferred, and view the signal on a waveform monitor.

- Turn off any modifiers to the gamma curve (knee, black stretch etc.) and adjust the exposure such that the peak white patch of the chart just produces peak white.
- Note the lens setting for this exposure ($F_{100\%}$)
- Turn on the knee function and set the knee point as low as it will go (typically 75%, but exceptionally 50% or even lower in some cameras). Set the slope control so the curve does not reach 100% even with 12 dB or more gain. This ensures that the camera's electro-optic curve can deal with a much larger exposure range than normal.
- Increase the exposure until the difference in signal level between the white patch and the next brightest patch starts to be unduly compressed. It may be necessary to adjust the knee controls until this condition is met. When met, adjust the slope control so the peak white patch just reaches 100%.

Note the exposure level for this setting (F_{max}). The difference between these values is the headroom in photographic stops.

$$HeadroomStops = F_{100\%} - F_{\max} \quad \text{or:} \quad Headroom = (F_{100\%} - F_{\max})^2$$

The minimum usable exposure (L_{min}) approximates to the rms value of noise, although this is usually defined by the manufacturers with gamma correction switched off, and so does not necessarily represent the noise level near black. Noise levels can be affected by the setting of black stretch/press, which is used primarily to reveal or conceal detail at very low signal levels, near black. Thus:

$$ExposureRange = Headroom / L_{\min}$$

2.4.2 Analytical method

The camera is framed on a back-illuminated test chart, and its output fed directly to a computer for analysis. The test chart is a transparency, or rather a set of transparencies mounted in an opaque metal plate, containing a number of specially manufactured patches of known density. The chart is intended to be used with back-illumination in otherwise total darkness. Therefore this is a technique purely for laboratory use; it is not practical to use it under any other circumstances, since stray light will inevitably pollute the image.

The adjustable 'speed' value of a camera that can be measured with a light meter is called the 'rating'. It relates to the object brightness reached by the Mapping Point M, in digital cinematography this brightness normally corresponds with 40% signal in the luminance channel.

Sensitivity is not a single value but is the distance from the Mapping Point M in the direction of lower object brightness to the point S (Threshold Value), the first point at which the digital signal is capable of conveying local information. This distance is given in apertures.

Dynamic range is the distance from the threshold value S to the clipping point C in f-stops.

A more direct and potentially far quicker and easier to implement method of measuring exposure range, is being developed by Dr. Hans Kiening of Arri.

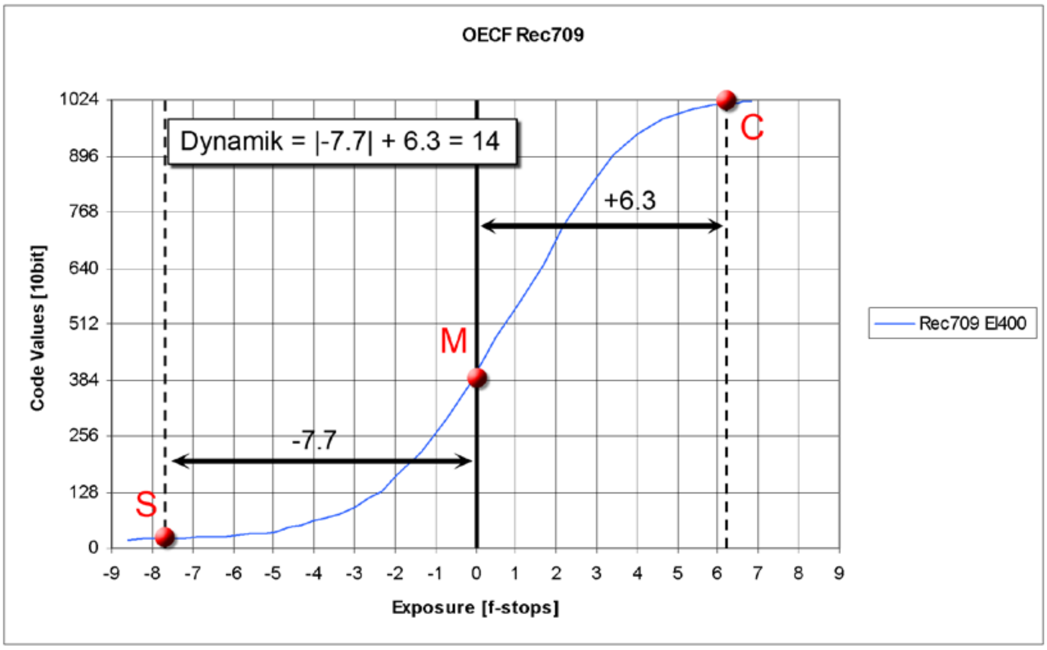
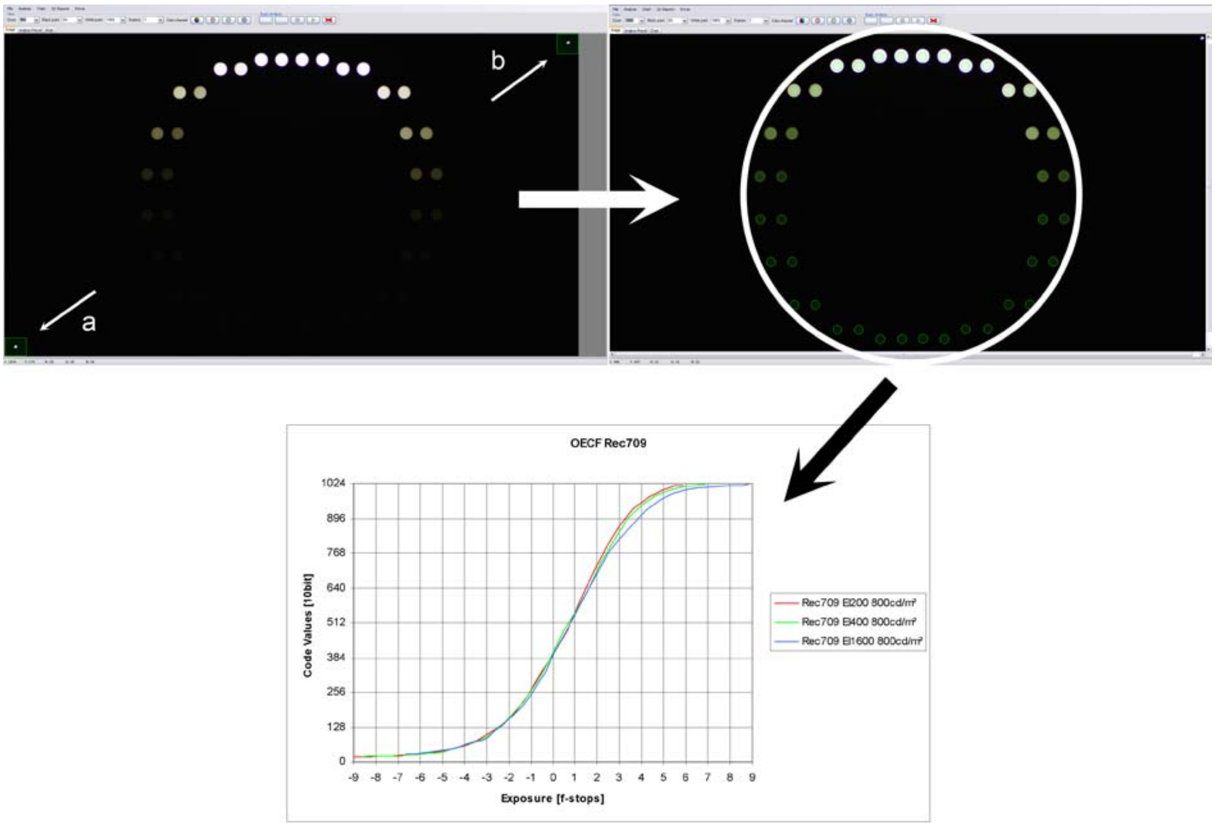


Figure 9: Exposure Range analytical method



2.5 *Colour rendering*

Set up a ColorChecker® test card, evenly illuminated. In practice, it is best to house the ColorChecker® chart in an internally illuminated box, with a colour-temperature shifting filter to achieve an illuminant correlated colour temperature of P3200, that of tungsten studio luminaires.

White balance the camera to the illuminant (use a Kodak Gray card, white side, as the reference, under the illuminant for the ColorChecker® card). Knee function should be turned off if possible, to avoid compressing highlights. If knee cannot be turned off, then the exposure level should be set such that the grey scale patches are not compressed near white.

2.5.1 Visual method

- View the video signal on a picture monitor.
- Next to the monitor, place another ColorChecker® test card evenly illuminated to Illuminant D65, the white balance point for television. This should also be housed in a light box, with a colour-temperature shifting filter to achieve D65, and will be referred to as the 'reference chart' below.
- Ensure that the display black level is correctly set, using either SMPTE or ARIB colour bars, such that the sub-black patches are not visible, but the super-black patches are visible.

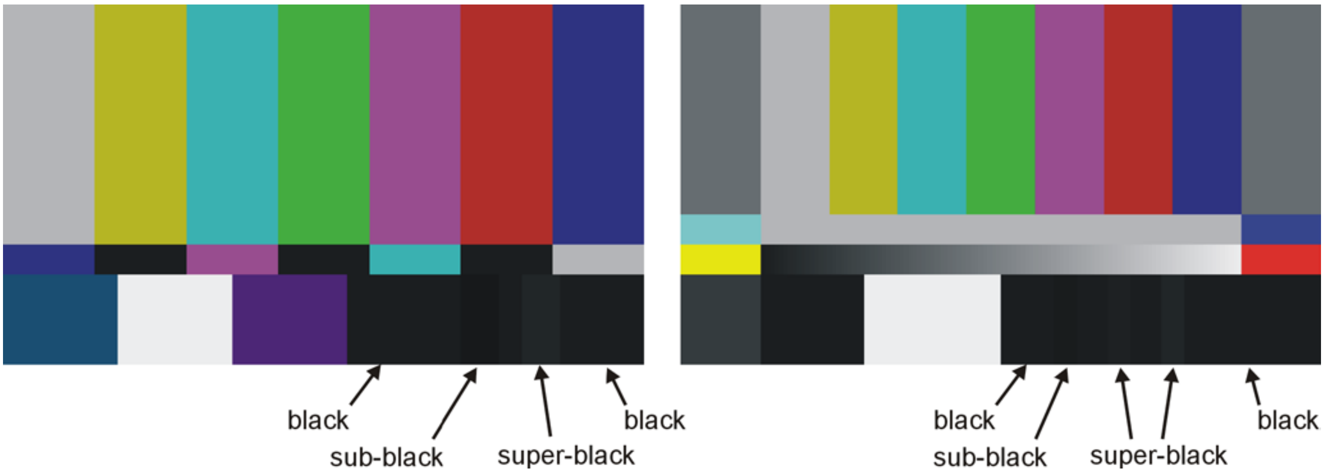


Figure 12: SMPTE & ARIB Colour bars showing correctly set black level

- Set the display saturation or colour control correctly. Colour bars provide the most reliable way to do this is;
  - Turn off the monitor's red and green drives.
  - Adjust the saturation/colour control until the division between the colour bars (top section, and the narrow section immediately below becomes indistinguishable.
  - Turn on the monitor's red and green drives.
  - Alternatively, if the monitor does not have controls to turn off red and green, then it is still possible to set the monitor approximately; use a sheet of lighting filter to pass only blue. Congo Blue[1] is the best available single filter, although it does not totally stop red and green emissions – it is better than nothing.
- Set the display contrast such that the ColorChecker® grey scale visually matches that of the reference chart.

Visually compare the patches of the image with those of the reference chart. Any significant differences should be noted, and the camera colour matrix and/or colour correction systems can be used to improve the performance where possible.

Note: It is generally not possible to obtain perfect colour rendering because there are too many parameters involved, but significant errors can usually be reduced using this method.

2.5.2 Analytical method

- Set up the ColorChecker® test card and camera as above, but turn off gamma correction if possible. If gamma correction cannot be turned off, the test results will be much less reliable.
- Capture an image as data and import it into specialised software for analysis.

The software analysis should measure the RGB video signal levels for each patch. These values can be compared with the calculated signal values for each patch (see **Annex 2**). Optionally, the software can be made to perform a linear matrix optimisation to improve the performance, using methods defined in EBU Tech 3237 and Tech 3237 Supplement 1.

[1] #181 in the Lighting Filters selections from Lee Lighting or ARRI

If the camera gamma correction cannot be turned off then the software should perform a reverse gamma-correction, using the inverse of the formula found by measurement, above (§ 2.1).

2.6 Infrared response

The camera should not respond to infrared illumination, since such illumination is not visible to the human eye. While the analytical measurement methods described in EBU Tech 3237 can be extended to produce a measure of the infrared response of the camera, a much simpler process can be used as a pass/fail test.

Since most (TVs, DVDs, etc.) consumer equipment's remote control units use infrared 'light' emitting diodes to communicate with the controlled device, the camera can be tested using the output of any such remote control. Set the camera up normally, point the remote control into the lens, and press any button. If the camera shows any video response, it must be responding to infrared power.

Figure 13: Infra red output of a remote control

The LEDs used in consumer controls emit power in the wavelength region of 800 - 900 nm, well outside the normal visual range of 380 – 760 nm.

Any camera found to be responding strongly to infrared should be fitted with an optical infrared-stop filter to make colour rendering reliable, and for black levels to be stable under changing illumination.

2.7 Spatial resolution, detail settings & aliasing

Set up a zone plate chart corresponding to the camera resolution, evenly lit, then white balance the camera to the illuminant. In order to obtain the best resolution results, the camera should be between 1 and 2 m from the chart, with the illumination level such that the chart can be correctly exposed with the lens aperture set to between F/2.4 and F/4.5.

Note: This set up is vital, not only for assessment of the camera resolution, but also for deriving settings for any detail control in the camera. There is no other test card suitable for this purpose.

Since the modulation of the chart is sinusoidal, it does not generate harmonic distortion in the image. The linear relationship between frequency and distance from the centre of each pattern allows frequency to be directly measured.

Aliasing can arise from the sampling structure of the sensors or from over excessive detail enhancement. It is important to separate these causes, and to be aware of them when deriving settings for the camera.

The zone plate test chart is designed for gamma-correction using ITU-R Rec. BT.709 gamma correction therefore gamma correction should be *set to **on*** for this test. Alternative versions of the zone plate test chart are available with low-level modulation, which is suitable for deriving linear measurements from the camera even though gamma correction is on.

Where the camera records onto local media (camcorder) and has simultaneous video output (SDI/HDSDI or HDMI) it is best to test both routes, since the camera can be used in both ways. This will reveal the nature of any sub-sampling and filtering in the recording process.

2.7.1 Visual method - resolution

- Switch off any camera detail control, so that the camera is delivering its native performance.
- View the image on the picture monitor and /or waveform monitor.

The resolution limits of the camera should be plainly visible on the luma (grey scale) pattern (horizontal frequency horizontally, vertical frequency vertically). Low frequencies should be clearly visible as sinusoidal variations in brightness, while frequencies beyond the limits of the camera should fade smoothly to mid-grey.

The frequency limits can be measured with a ruler or using the waveform monitor's graticule markings, since the individual patterns have a linear relationship between frequency and radius. Should there be any imbalance between the frequency limits of red green and blue, these should be noted, as they give insightful information regarding the structure of the sensors and the signal process.

2.7.2 Analytical method – resolution

- Switch off any detail controls in the camera.
- Capture a frame image and import it into suitable software.
- Export horizontal and/or vertical sweeps through the centre of the patterns of interest, forming a series of video samples.
- Import these into a spreadsheet and plot the results as a graph.

This will show the frequency response directly, as a set of sample values. While it is possible to reconstruct a smooth frequency response curve by passing the data values through an up-sampling reconstruction filter, it is rarely necessary. A smooth curve can easily be estimated from the envelope of the data values (the blue, pixel values).

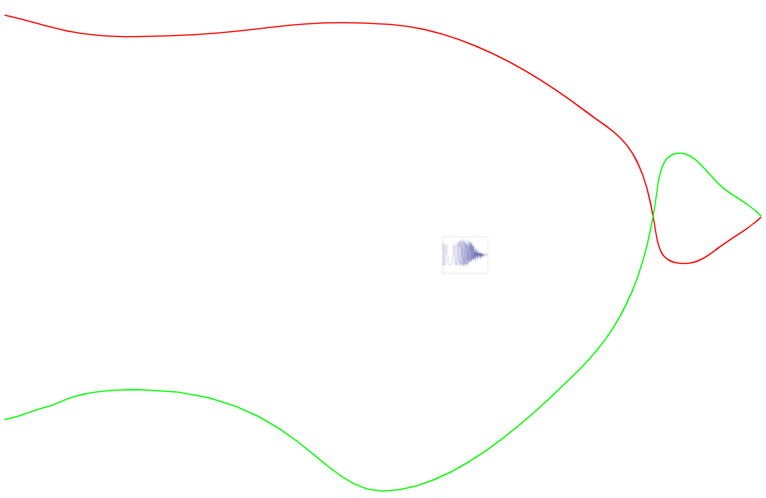


Figure 14: Camera spatial frequency response

Note that the upper and lower envelopes of these curves (red and green lines) may not be symmetrical, because of the effects of gamma correction. Therefore, results obtained in this way should be regarded only as indicative of frequency response and resolution, and cannot be used for any other purpose.

2.7.3 Visual method – detail settings

The derivation of detail-enhancement settings for individual programme genres is difficult and subjective; it is generally not possible to derive one setting which will please all users.

If the camera has factory settings for detail, then the brightness of the central, preserved, frequencies may be artificially raised due to detail enhancement. Improved settings for detail control can be derived by inspection of this pattern, ensuring that the central part is not over-brightened, and that the outer limits are enhanced to suit the programme-type. The camera may have separate controls for detail enhancement and for aperture correction; a combination of these adjustments may be used to obtain best results. Video-style production will normally require more detail enhancement at lower frequencies than film-style production, which would normally require a little more enhancement at the highest possible frequencies.

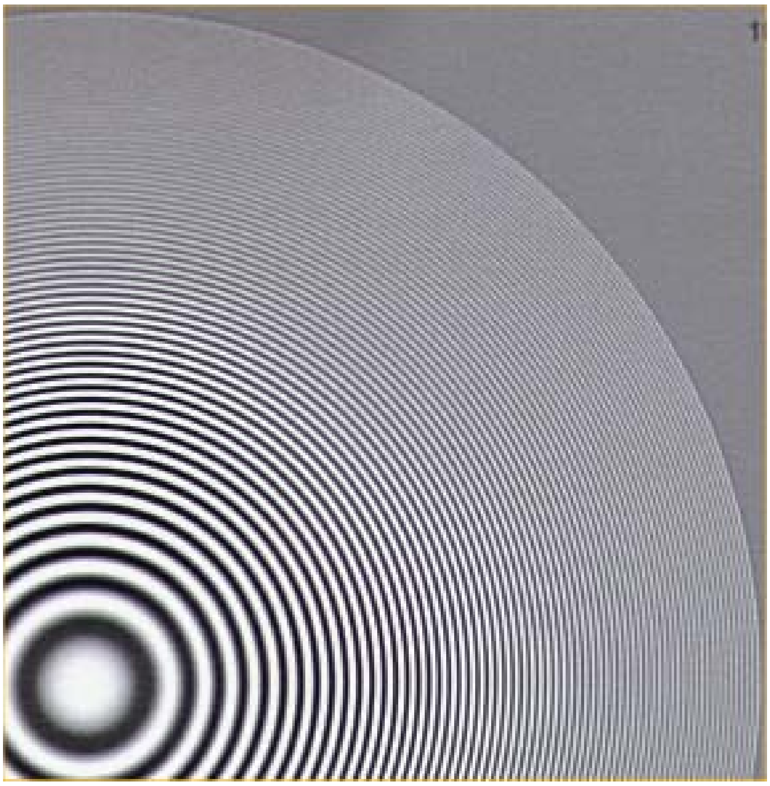


Figure 15: LDK3000 default - smooth resolution with no aliasing

When adjusting camera controls for detail, it is important to check the reproduction of sharp black/white transitions in the greyscales and in the radial, ‘starburst’, patterns at the corners of the chart. These edges should not overshoot significantly, and any overshoots should be equally balanced. Positive (black to white) and negative (white to black) going transitions should be symmetrical for best results.

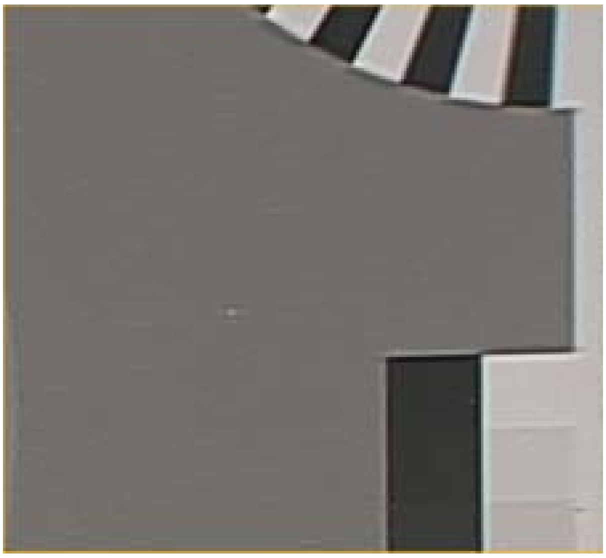


Figure 16: HFD V10 – overshoot between black/white transitions

2.7.4 Analytical method – detail settings

It is not possible to set detail controls by any analytical means, since the effects of the controls must be seen in real-time. However, the process is ideal for recording the result of visually achieved settings. Capture a frame of video and follow the processes described above (§ 2.7.2).

2.7.5 Visual method – aliasing

- View the camera output on the picture monitor.

If they exist, alias patterns will be evident as sets of concentric modulation centred away from the true centre of the pattern. The centres of any alias patterns will be visible as 'null zones' at frequencies defined by the sampling structure of the sensor. This is incontrovertible evidence of the sensor resolution.

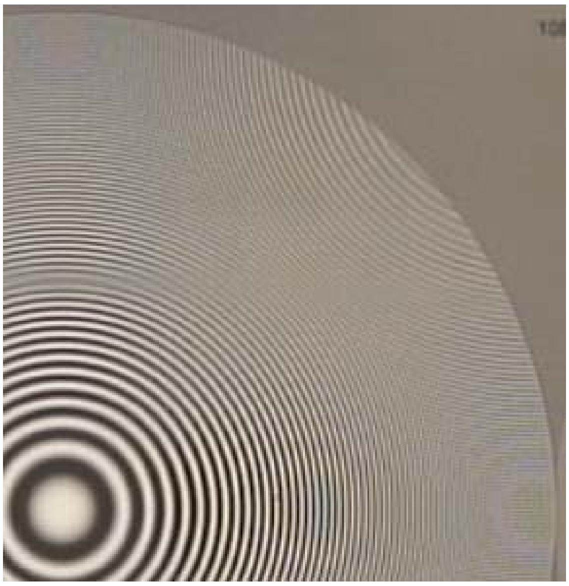


Figure 17: Example of alias patterns on a zone plate

In this example, spatial aliases are visible, not only horizontally and vertically, but diagonally as well. The null zones centred (approximately) at the horizontal and vertical extremes indicate that the lens is delivering spatial detail up to the limits of the zone plate pattern, but that the camera cannot properly resolve such frequencies.

By examining the zone plate pattern in primary colour-separations, more information can be extracted.

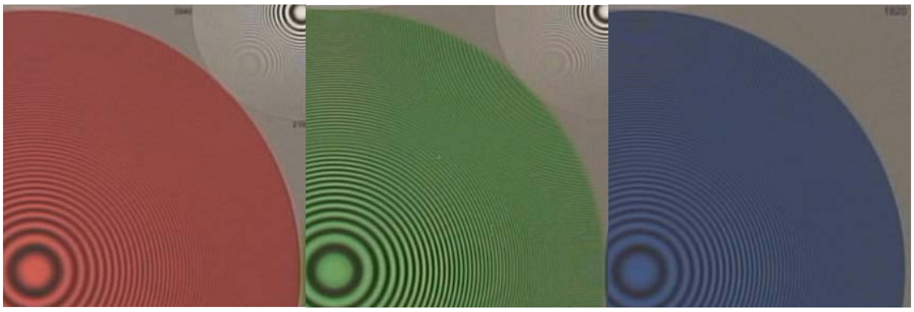


Figure 18: Colour separations of the zone plate alias pattern

In this example, it is evident that the sensor resolutions are not equal; the red and blue sensors are half-normal resolution, while the green sensor has normal resolution/$\sqrt{2}$ and is rotated by 45°. This is clear proof that the camera has a single sensor, with the classic Bayer pattern of colour filtering.

Similarly, examination of the primary colour-separations can identify 'precision-offset' 3-sensor structures, where the green sensor is spatially offset from both red and blue by exactly half a photo-site, to improve horizontal resolution at the expense of some spatial aliasing. In other cameras, the green sensor is offset from red and blue in both horizontal and vertical directions, the so-called 'quincunx' arrangement. This produces resolution similar to that of a single Bayer-patter sensor, with spatial aliases in both directions.

2.7.6 Analytical method – aliasing

- Capture a frame and import into suitable software[1].
- Export horizontal and/or vertical sweeps through the patterns as data, and import into a spreadsheet.
- Plot the results as a sampled waveform.

The upper and lower envelopes of the waveforms will pass through zero at the centres of the null zones, which can be measured accurately.

Frequency content beyond a null zone caused by the sampling structure is amplitude inverted (black to white, white to black). Frequency content beyond the centre of a null zone caused by detail enhancement is not inverted because the null zone is caused by harmonic distortion rather than by sub-sampling. It is important to draw this distinction.

2.8 Lens/optical effects

- Set up the zone plate, evenly illuminated
- In order to obtain the best resolution results, the camera should be between 1 and 2 m from the chart, with the illumination level such that the chart can be correctly exposed with the lens aperture set to between F/2.4 and F/4.5.

If the camera has any form of automatic correction for lens defects (e.g. chromatic aberration), then this test should demonstrate its efficacy.

[1] The software bundle provided with this document can be used if the user has no better software solution.

2.8.1 Visual method

- View the picture on the picture monitor.
- Examine the corners of the image for any softening or colour fringing effects. When the lens is set to its optimum settings, there should be no such visible effects.
- Open the lens fully and adjust the camera gain or neutral density filters to maintain correct exposure.
- Examine the corners again for aberrations.
- Progressively close the lens down and adjust the gain or neutral density filters to maintain exposure.

At some aperture setting, the image will start to soften, this is the point at which iris diffraction starts to become significant, and it can be regarded as the limit beyond which the lens should be stopped down for best performance.

Repeat the test at various chart-to-camera distances to explore the operating range of the lens. This is not normally required for HD lenses, but it can be used to establish the cause of lens defects if there are present.

2.8.2 Analytical method

- Capture images and import them into specialised software.

There is no need for mathematical analysis of data from these images; the capturing is merely for the purpose of recording the effects, and measuring the magnitude of them.

The most common lens defect is chromatic aberration, which will always be worst in the corners of the images.

- Measure the shift of the red green and blue image planes with respect to each other, both horizontally and vertically.

Normally, only horizontal aberrations will be visible because the image is much wider than it is high (for 16:9 images). However, since automatic chromatic aberration correction usually only works horizontally, a poor lens may well show more vertical aberration than horizontal when it is not being corrected.

Note: As mentioned in §1.2 a more detailed description of the lens performance can only be obtained by testing the lens in isolation in a specialised optical test bench. By analysing the Modulation Transfer Function (MTF) of the lens one will get a detailed overview of the optical resolution or sharpness of the image formed by the lens. See EBU Tech 3249 (under revision) for definitions and measurement procedures. A document on the requirements for HDTV lenses is under development by the EBU.

2.9 Temporal/shutter effects

Cameras with CCD sensors usually exhibit no odd temporal effects, but cameras with one or more CMOS sensor can produce visible effects from the use of a ‘rolling shutter’. The effect is identical to that seen in focal plane film stills cameras; leaning verticals, distorted edges, and jelly-like images from rapid motion. A multi-bladed variable speed fan is needed for these tests.

2.9.1 Visual method

- Set the fan, brightly illuminated.
- Position the camera at a convenient distance.
- Set the shutter to its nominal value (1/50 second for 50 Hz, 1/60 for 59.94 Hz, or 180 degrees for either).
- View the pictures on the picture monitor.
- Vary the fan speed while watching the images.

A camera with a ‘rolling shutter’ will show asymmetrical blades, a CCD camera will not. The blades can be ‘frozen’ in the image when the fan speed is set to any harmonic of the scan speed:

$Speed = N\frac{3000}{b}$ rpm for 50 Hz cameras or $Speed = N\frac{3600}{b}$ rpm for 60 Hz cameras

Where N = Nominal shutter speed and b = number of fan blades

To exaggerate the effect, reduce the camera shutter setting; typically, 1/1000 second should be enough. At this speed or higher, it will be possible to produce frozen images of the blades that show significant distortion.

2.9.2 Analytical method

Follow the procedure above (§2.9.1) and capture images as required. No mathematical analysis is needed as the images are captured only for recording the effect.

3. Presentation of results

The results of measurements can form a useful reference document, summarising the camera’s performance, and listing the contents of the control menus. It should not be thought of as a substitute for the camera’s manual, but as an addition to it, summarising the camera’s capabilities.

The presentation should comprise:

- An introductory section describing the salient features of the camera under test, pointing out any unusual features.
- A listing of the control menu contents. Items in the menus which affect the image quality, and for which preferred settings have been derived that differ from the factory default values, should be highlighted to attract the reader’s attention. Footnotes can be useful in explaining the preferred settings.
- Results of measurements. Verbal descriptions of results from visual inspection need not be complex. It is only necessary to state that such an inspection has been made, and whether the camera has performed to expected levels or not. Pictorial, graphical or numerical results from analytical measurements should be accompanied by text that explains why the measurements were made, together with an interpretation of the results.
- A simple explanation of any Tier given to a camera as a result of the test with specific reference to the six points detailed in §5.

An example of a full camera measurement report is given in **Annex 7**.

4. Derivation of preferred settings

While measurement of camera parameters is purely scientific, the derivation of preferred settings for a camera is largely an artistic process. Preferred settings for one programme type may not be suitable for another and are far more dependent upon the opinions of the programme-makers rather than those of technologists or engineers.

Therefore, it is usually true that when attempting to choose preferred camera settings, more than one set will be required. With that in mind, it is useful to list the major programme-types together with the customary camera performance that is traditionally expected for such programmes.

Table 2: Preferred camera settings for major programme types

Genre	Image rate	Resolution	Detail enhancement	Contrast handling
Drama	Low	High	Low	Low (studio)
				High (location)
Wildlife and Natural History	Low	High	Low	Very high
		Low		
Light Entertainment	High	High	High (50 Hz)	Low (studio)
	Low		Low (25 Hz)	High (location)
Sport	High	High	High	Low (indoor)
				High (outdoor)
Journalism	High	High	High	Low (studio)
	Low	Not critical	Low	High (location)
News	High	Not critical	Not critical	Not critical

The early development of television has created the traditions for these preferences, and they may not be the same in all countries.

4.1 Image rate

The use of low image (frame) rate for drama and wildlife programmes derives from the early use of film shot at 25 frames per second at a time when video recording was not feasible. Programme makers and the audience have become accustomed to the repeated-image presentation of film for this type of programme, and expect it when shooting with video cameras. This has created a desire for a ‘film look’, in which many of the symptoms of film are replicated electronically.

Entertainment and other studio-based programmes usually have a smooth or “video” motion, and a 50 fields per second ‘look’ is expected.

As programme making has steadily moved away from film into video, producers have been able to make choices such as setting cameras in many combinations of settings to achieve previously impossible ‘looks’.

4.2 Resolution

Generally it is expected that high-definition television images will be well defined but there are occasions where lower definition is acceptable. When cameras are placed in unusual or dangerous positions, or when special effects are needed (for example, extreme slow-motion using high-speed cameras), then lower resolution is inevitable.

Generally, low-resolution cameras or camera settings should not be used where high-resolution cameras are available.

4.3 Detail enhancement

High-end cameras always have the option to manipulate the frequency content of the image. There are usually many controls to enhance detail, and very occasionally to reduce detail. Careful combinations of settings can achieve a wide range of picture effects.

For programmes traditionally shot on film, a softer picture is generally preferred, since high-definition cameras can produce higher-amplitude detail at high frequencies than is delivered by film when scanned for television.

Programmes traditionally shot on video cameras usually have a sharper 'crisper' look. This is usually achieved by over-amplifying the edges of shapes. In the extreme, this can give rise to shadow outlines that may be objectionable, but in high-definition cameras this can be avoided while still giving crisp-looking pictures.

Manipulation of detail enhancement settings is difficult to do without using a test card, and is very difficult to do using small monitor displays. It is never satisfactory to set detail on a general scene, since unexpected effects will become apparent when the scene changes. The best method is to use a zone-plate chart under controlled conditions.

- **Low-detail, smooth, film-look**. Set the boost frequency to its highest value then increase the detail level until the lower frequencies appear to be gaining in contrast, but only marginally. It may be necessary to adjust balancing controls, separate controls of positive- and negative-going edges, and of horizontal and vertical detail, to keep the picture looking neutral. The detail level should never be set so high that high-contrast edges (i.e. black-to-white and white-to-black) overshoot. It may also be necessary to adjust clipping controls to prevent large enhancements, and to avoid enhancing video noise.
- **High-detail, video-look**. Set the boost frequency to a mid value and then raise the detail level until the lower frequencies gain in contrast, but not excessively. Use the horizontal/vertical, positive/negative controls to maintain neutrality in the pictures. Moderate overshooting on high-contrast edges is acceptable, it is a signature of the 'video-look'

4.4 Contrast handling

Wildlife and natural history programmes recording natural scenes require the capture of a large contrast range. Negative film does this well, handling at least 14 photographic stops or dynamic range, however video cameras cannot usually handle such a high range. A typical broadcast camera with video noise levels of about -50dB can capture about 7.5 stops, with the controls set to factory settings.

At low exposure levels, video signal noise will predominate, obscuring detail in deep shadow. If the noise level is particularly high, then the effective dynamic range will be reduced by about 1 stop per 6dB of video noise level increase.

At high exposure levels, the sensor's dynamic range may be exceeded, resulting in video clipping. However, most cameras do not normally use the entire dynamic range of the sensor, and can be set to capture at least 1 extra photographic stop by manipulation of the gamma curve and/or knee. In some extreme cases, cameras can capture up to 3 extra stops, and effectively handle 12 to 13 stops of dynamic range, very close to that of negative film.

Black-stretch (and black-press) can be useful, allowing direct control over the slope of the lower part of the gamma curve. Black-stretch reveals dark detail, black-press conceals it. Applying black-stretch involves raising the gain near black, which will inevitably increase the noise level near black. It is always better to have higher gain near black in the camera rather than to apply it in post-production, because fewer data-compression artefacts will be generated in the camera recording.

Low-contrast performance. Scenic contrast is effectively expanded. Set the gamma curve to either the BBC0.4 or ITU.709 curve, and set white clipping to not greater than about 104%. This will prevent signal excursions beyond peak white causing problems in analogue transmission systems.

High-contrast performance. Scenic contrast is effectively compressed. Two approaches are possible.

- If the camera has specific film-look gamma curves, use them.
  - There may be several curves available, for high- and low-contrast scenes, and for shooting conditions which allow signals to excurse only to peak white level (100%) or to the full signal range (109%). If the programme is to be shot live or as-live (i.e. there will be no post-processing) then always use curves that do not exceed 100%.
- If the camera has no specific film-look curves, then use the ITU.709 gamma curve.
  - Set the knee function on (manual knee) and the knee point to between 80% and 90%. This will ensure that skin tones remain in the normal part of the gamma curve.
  - Adjust the knee slope so it accommodates the desired degree of overexposure. In a normal gamma curve, the top 14% of the video signal range contains about 1 stop of exposure range, but by setting a lower slope to the knee function, this can be raised by at least one stop.

Beware of attempting to accommodate all the over-exposure that the camera can deliver, most camera operators will avoid using this range because the highlight compression will appear to be too high, unless the knee point is set lower (e.g. to about 75% or lower for wildlife shooting) when extra overexposure range does not look abnormal.

When setting the knee function, it is best to use the camera's internal sawtooth test signal and a waveform monitor.

- Set the camera gain to +6dB to set a curve to handle 1 stop of overload, +12dB to set for 2 stops and so on. If the camera has no internal sawtooth test signal, then a grey scale can be used, the ColorChecker® chart is suitable.
- Set the knee point and slope, using the signal levels of the bottom-row grey-scale as indicators of the gamma-curve performance.

It is not possible to produce a comprehensive range of camera settings to satisfy all these needs, but it is perfectly possible to derive settings for individual requirements, parts of which can then be used separately or together, to satisfy the taste of other programme-makers.

5. Bibliography

R. M. Evans	**Eye, film and camera in color photography**	*John Wiley, new York; Chapman & Hall, London, 1959.*
C. S. McCamy, H. Marcus and J. G. Davidson	**A color-rendition chart**	*Journal of Applied Photographic Engineering, Vol. 2, #3, Summer 1976.*
J. O. Drewery	**The zone plate as a television test pattern**	*BBC Research Department Report 23, 1978*
A. Roberts	**Colorimetric and resolution requirements of cameras**	*BBC Research and Development Department White Paper 034, 2002.*
A. Roberts	**Circles of confusion**	*EBU Technical, Geneva, 2009.*

With thanks to Dr Hans Kiening for allowing his work to be represented in this document

Annex 1: Kodak Gray Cards

Kodak Gray cards have been used in the photographic industry for decades. They operate on the principle, propounded by Ralph Evans, that the mean reflectance of a scene is 20% of the peak reflectance, ignoring any illuminators (visible lamps, skylight, the sun etc.).

In 1959, Evans described the use of standard cards, with 17% reflectance on one side, and 85% on the other, but more recent cards are 18% on one side, 90% on the other. Both sets accurately maintain the 5:1 reflectance ratio claimed by Evans.

The cards maintain reflectance values with a tolerance of ±2% over the wavelength range 400 – 700 nm. Thus they can be safely used as reference reflectors for the purposes of camera measurement. The curves below are taken from Kodak's published documentation.

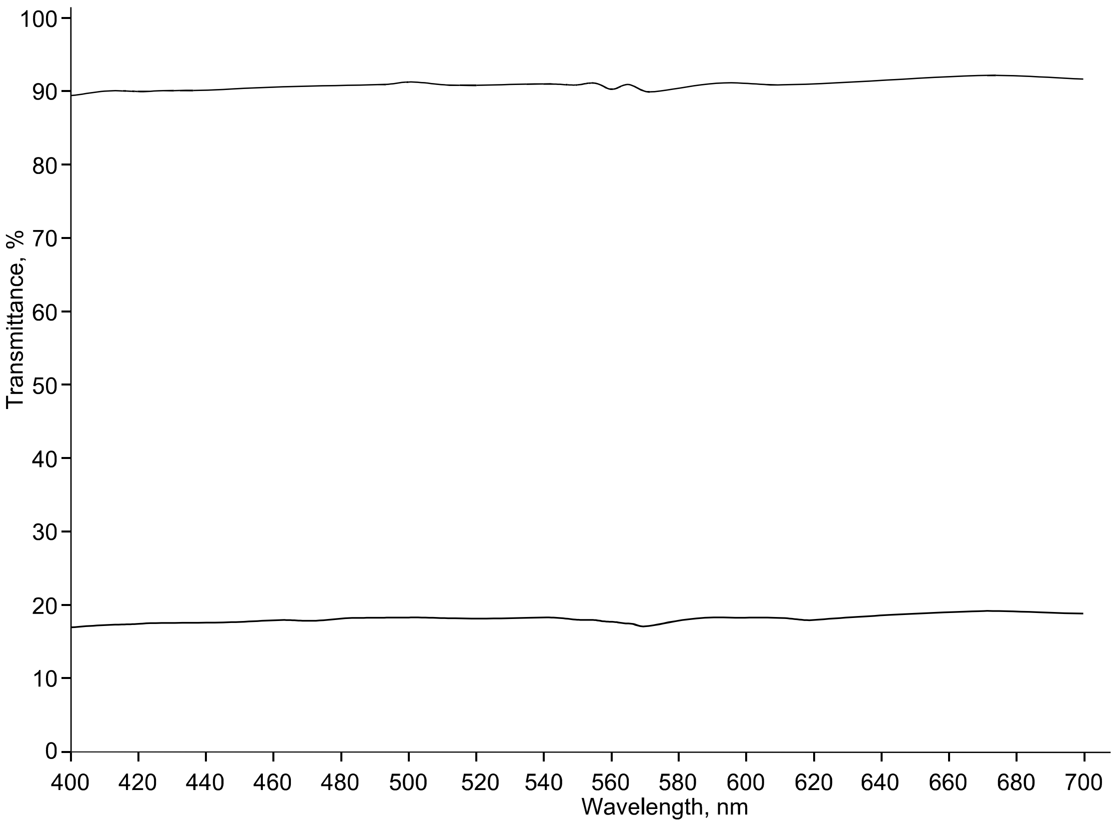


Figure 17: Kodak Gray Cards reflectance measurement

Page intentionally left blank. This document is paginated for two sided printing

Annex 2: ColorChecker®

Originally known as the 'Macbeth' chart, the ColorChecker® was introduced in 1976 by McCamy, Marcus and Davidson, all of whom worked for Macbeth, then a division of Kollmorgen Corporation. Their paper lists the colours, and gives accurate colorimetric data for each colour patch when lit by Illuminant C which was the white balance colour for NTSC television. Independent spectro-radiometric measurements of two original Macbeth cards produced results which agree well with these values. However since then all televisions standards have adopted Illuminant D_{65} for the white balance point.

Recently produced cards are supplied with calibration data for sRGB primaries (i.e. ITU-R BT.709, which is correct for HDTV, but refers to gamma-corrected R'G'B' values rather than the more accurately achievable linear RGB values) and in CIE L*a*b* values when illuminated with Illuminant D_{50}.

Data values in the following table are derived from the original data (McCamy, Marcus and Davidson), rebalanced and analysed for illumination with D_{65}. Linear RGB values are calculated for both EBU (SDTV) and ITU-R Rec. BT.709 (HDTV) primaries, gamma corrected values are calculated using the BBC 0.4 law for SDTV and the ITU-R Rec. BT.709 law for HDTV.

Colours #6 and #11 are critical; they can easily lose their difference when there is a problem in the camera blue channel spectral responsivity curve. Colour #13 can appear red if there is a problem in the red responsivity. Colour #18 cannot be reproduced accurately by a television system with EBU or ITU-R Rec. BT.709 primaries since it falls outside the gamut of the primaries, but the error is small.

		EBU						ITU.709					
		R	G	B	R'	G'	B'	R	G	B	R'	G'	B'
1	Dark Skin	0.185	0.082	0.064	0.488	0.325	0.281	0.190	0.082	0.064	0.421	0.257	0.220
2	Light Skin	0.604	0.302	0.254	0.812	0.606	0.562	0.617	0.302	0.255	0.785	0.542	0.495
3	Blue Sk	0.125	0.199	0.378	0.405	0.504	0.667	0.121	0.199	0.376	0.327	0.432	0.608
4	Foliag	0.109	0.153	0.055	0.380	0.447	0.255	0.107	0.153	0.056	0.304	0.373	0.201
5	Blue Flower	0.237	0.216	0.482	0.545	0.523	0.740	0.238	0.216	0.479	0.477	0.453	0.690
6	Bluish Green	0.144	0.512	0.443	0.434	0.758	0.714	0.128	0.512	0.444	0.336	0.714	0.664
7	Orange	0.699	0.190	0.026	0.863	0.493	0.131	0.721	0.190	0.028	0.850	0.421	0.121
8	Purplish Blue	0.062	0.104	0.409	0.275	0.370	0.690	0.060	0.104	0.405	0.210	0.298	0.633
9	Moderate Red	0.554	0.086	0.140	0.784	0.336	0.428	0.575	0.086	0.139	0.758	0.266	0.354
10	Purple	0.110	0.043	0.171	0.381	0.211	0.470	0.113	0.043	0.169	0.313	0.167	0.395
11	Yellow Green	0.387	0.490	0.049	0.674	0.745	0.235	0.382	0.490	0.054	0.614	0.698	0.197
12	Orange Yellow	0.793	0.340	0.026	0.909	0.638	0.130	0.813	0.340	0.030	0.902	0.577	0.127
13	Blue	0.016	0.056	0.300	0.078	0.259	0.605	0.014	0.056	0.298	0.062	0.202	0.538
14	Green	0.082	0.298	0.071	0.325	0.603	0.301	0.072	0.298	0.074	0.238	0.539	0.241
15	Red	0.448	0.018	0.045	0.717	0.088	0.219	0.467	0.018	0.044	0.681	0.079	0.171
16	Yellow	0.855	0.538	0.015	0.938	0.774	0.077	0.868	0.538	0.022	0.932	0.732	0.097
17	Magenta	0.490	0.083	0.341	0.744	0.328	0.639	0.508	0.083	0.338	0.711	0.259	0.576
18	Cyan	-0.018	0.246	0.415	-0.088	0.554	0.694	-0.029	0.246	0.413	-0.131	0.485	0.640
19	White	0.943	0.877	0.991	0.976	0.948	0.996	0.946	0.877	0.989	0.973	0.937	0.995
20	Neutral 8	0.619	0.576	0.650	0.821	0.797	0.838	0.621	0.576	0.650	0.788	0.758	0.806
21	Neutral 6.5	0.379	0.353	0.398	0.668	0.648	0.682	0.381	0.353	0.398	0.612	0.589	0.627
22	Neutral 5	0.207	0.193	0.218	0.513	0.497	0.525	0.208	0.193	0.217	0.443	0.425	0.454
23	Neutral 3.5	0.094	0.088	0.099	0.352	0.338	0.361	0.095	0.088	0.099	0.281	0.269	0.289
24	Black	0.033	0.031	0.034	0.164	0.153	0.172	0.033	0.031	0.034	0.137	0.130	0.142

Page intentionally left blank. This document is paginated for two sided printing

Annex 3: Standard gamma-correction curves

There have been many attempts to derive an ideal gamma-correction curve for cameras. Many broadcasters and camera manufacturers have derived proprietary curves which they consider to be most appropriate for their own purposes. Some of these have become standardised, and are listed here.

In general, the higher the slope of the curve in the linear part, and the lower the value of the power function, the better is the colour reproduction accuracy, but the more noise is present in the images. Normally, the linear part meets the curved part tangentially, smoothly, but some of the curves do not quite get there.

The table gives the output level at which the slope of the curve is unity is given as a guide to the video level to use when the gamma-correction cannot be switched off.

	Equation, V'=	Break at V=	Linear slope	Unity slope point	20% input	50% input
ARD	$1.111V^{0.45} - 0.111$	1.8%	4	28.4%	42.7%	70.2%
AHEG-C	$1.1V^{0.45} - 0.1$	1.8%	4.5	27.5%	43.3%	70.6%
BBC 0.4	$[(V - 0.02262)/(1 - 0.02262)]^{0.4}$	3.7703%	5	24%	50.5%	75.1%
BBC 0.5	$[(V - 0.01011)/(1 - 0.01011)]^{0.5}$	2.0202%	5	26%	43.8%	70.3%
BBC 0.6	$[(V - 0.01011)/(1 - 0.01011)]^{0.5}$	0.8357%	5	28%	37.8%	65.9%
IEC sRGB	$1.055V^{1/2.4} - 0.055$	0.304%	12.923	24%	48.5%	73.5%
ITU-R Rec. BT.709	$1.099V^{0.45} - 0.099$	1.8%	4.5	27.8%	43.4%	70.6%
ENG 3.0	$1.04V^{0.6} - 0.04$	1.9%	3	30.5%	35.6%	64.6%
ENG 3.5	$1.085V^{0.5} - 0.085$	2.7%	3.5	29.3%	40.0%	68.2%
ENG 4.0	$1.11V^{0.45} - 0.11$	2.4%	4	28.2%	42.8%	70.2%

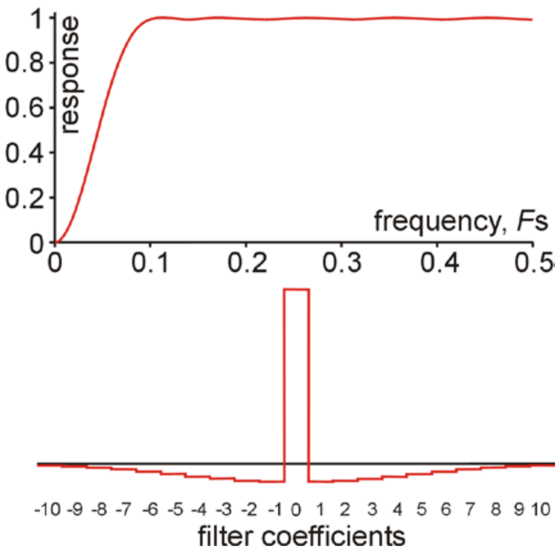
Page intentionally left blank. This document is paginated for two sided printing

Annex 4: High-pass noise filter

High-pass filtering removes all low frequency image content, such as is caused by illumination shading, both horizontal and vertical. Ideally the filter should pass as much as possible of the image content unaffected, but practicalities impose some limitations on filter design.

The filter must have zero response to steady state conditions (i.e. zero frequency) . An ideal filter which has a low cut-off point (at which the response is -6 dB), designed using the Remez-exchange principle, has 271 coefficients, which would be almost impossible to use on a video signal. The filter described below, has only 21 coefficients, is substantially flat with 0 dB attenuation from 9% to 50% of the sampling frequency, and is -6 dB at 4.5%.

In frequency terms, assuming an HDTV system with 74.25 MHz sampling rate, the filter is -2 dB at 3.34 MHz, and is flat from 6.6 MHz and upwards. Although not ideal, the filter is manageable and has already been used for several years for noise measurements. For measurement purposes, a constant offset must be added, such that the resultant data image is not centred on zero video level.



Term	Value
0	0.5+0.907269580
1, -1	0.5-0.090527253
2, -2	0.5-0.084189316
3, -3	0.5-0.074463811
4, -4	0.5-0.062454811
5, -5	0.5-0.049445500
6, -6	0.5-0.036689456
7, -7	0.5-0.025240896
8, -8	0.5-0.015810678
9, -9	0.5-0.0087298032
10, -10	0.5-0.0045701326

Page intentionally left blank. This document is paginated for two sided printing

Annex 5: ITU video coding equations

For image manipulation in software, the data values for individual pixels must first be decoded, effectively to analogue values (floating point). Operating on the data in quantised form is not sufficiently accurate, particularly for filtering and noise measurement.

SDTV coding equations, ITU-R Recommendation BT.601

The analogue equations are:

$$Y' = 0.299R' + 0.587G' + 0.114B' \qquad R' = Y' + C_R/0.713$$
$$C_B = 0.564(B' - Y') \qquad B' = Y' + C_B/0.564$$
$$C_R = 0.713(R' - Y') \qquad G' = (Y' - 0.299R' - 0.114B')/0.587$$

The digital equations for 8-bit coding are:

$$R'_D = 219R' + 16Y'_D$$
$$G'_D = 219G' + 16$$
$$B'_D = 219B' + 16$$
$$Y'_D = 219Y' + 16 = (77R'_D + 150G'_D + 29B'_D)/256$$
$$P_B = 224 * 0.564(B' - Y') + 128 = 126(B' - Y') + 128 = (-44R'_D - 87G'_D + 131B'_D)/256 + 128$$
$$P_R = 224 * 0.713(R' - Y') + 128 = 160(R' - Y') + 128 = (131R'_D - 110G'_D - 21B'_D)/256 + 128$$

$$Y' = (Y'_D - 16)/219$$
$$R' = (P_R - 128)/160 + Y'$$
$$B' = (P_B - 128)/126 + Y'$$
$$G' = (Y' - 0.299R' - 0.114B')/0.587$$

For 10-bit coding, the integer numbers above are each multiplied by 4.

HDTV coding equations, ITU-R Recommendation BT.709

The analogue equations given are:

$$Y' = 0.2126R' + 0.7152G' + 0.0722B' \qquad R' = Y' + C_R/0.6350$$
$$C_B = 0.5389(B' - Y') \qquad B' = Y' + C_B/0.5389$$
$$C_R = 0.6350(R' - Y') \qquad G' = (Y' - 0.2126F' - 0.0722B')/0.7152$$

The digital equations for 8-bit coding are:

$$R'_D = 219R'+16$$
$$G'_D = 219G'+16$$
$$B'_D = 219B'+16$$
$$Y'_D = 219Y'+16 = (54R'_D + 183G'_D + 18B'_D)/256$$
$$P_B = 224 * 0.5389(B'-Y') + 128 = 138(B'-Y') + 128 = (-26R'_D - 86G'_D + 111B'_D)/256 + 128$$
$$P_R = 224 * 0.6350(R'-Y') + 128 = 163(R'-Y') + 128 = (112R'_D - 102G'_D - 10B'_D)/256 + 128$$

$$Y' = (Y'_D - 16)/219$$
$$R' = (P_R - 128)/160 + Y'$$
$$B' = (P_B - 128)/126 + Y'$$
$$G' = (Y' - 0.2126R' - 0.0722B')/0.7152$$

For 10-bit coding, the integer numbers above are each multiplied by 4.

Annex 6: Programs for data processing

This document describes a suite of programs, written for colorimetric analysis of single frames extracted from digitally captured video sequences. Anyone writing software to perform such actions would normally concatenate the processes, but here, separation aids comprehension. The programs are all written in BBC BASIC for Windows, and the routines have been kept as simple as possible. BBC BASIC for Windows can be read almost as plain English, and therefore should be readily understood by anyone familiar with any form of computer programming.

Each program is supplied as a stand-alone EXE file, and as a pdf file. The pdf versions contain comments to explain the algorithms where necessary.

The programs all work, but they should be regarded as examples of algorithms, rather than as useful for practical measurements. They work best when the computer display screen is larger than the image format: for working on images of 1920 x 1080, the display should be at least 1920 x 1145.

They will work with smaller displays but the image files will not be displayed correctly, although the file processing will still be correct.

Each program performs one simple task, and only that task.

There are eight programs:

1 Make YUV BMP from RAW YUV file

Read a file of uncompressed YUV data, 4:2:2 subsampled and 8-bit coded, and generate a Windows bitmap file (BMP) from it. The raw file is assumed to have been captured from a ‘DVC ClipRecorder XTreme’, which creates data files without headers, simply a stream of pixel values starting from the top left of the image.

The BMP file contains the U (Cb) channel in the B plane of the BMP file, Y’ (luma) in the G plane, V (Cr) in the R plane. The chroma channels are not interpolated in this process, for pixels where there is no chroma sample, the chroma channel levels are set to zero (level 128 in the file).

The output file is created in the same location as the source file, and has the same name, but with an extra extension of .bmp.

2 Interpolate 422 YUV BMP

Read a file such as that created by program #1, and interpolate the chroma samples to insert values at alternate sites, where they are missing in the original.

The original file is modified, no new file is created.

3 Make RGB BMP from YUV BMP

Create a new BMP file in conventional RGB format, from a file such as that created and interpolated in program #2. The decoder equations are specified in a text file (supplied) and therefore can be modified by the user.

The output file is created in the same location as the source file, and has the same name, but the extension will be “-rgb.bmp”.

4 Analyse, full screen

Measure the mean pixel values (RG and B) in a conventional BMP file. The measurement area can be resized and moved using the cursor keys (instructions are given in the program). Once mean values are calculated, noise levels are calculated for the three channels. Mean and noise levels for Y' (luma) are also calculated.

No output file is created.

5 Make filtered copy of file

Apply a high-pass filter to each plane of a BMP file. The filter coefficients are defined in a text file, and therefore can be modified by the user. The filter supplied has zero response at dc, 100% response at 10% of sampling frequency, and passes through a -6dB point at 4.5% of sampling frequency. Only horizontal filtering is implemented, vertical filtering is not needed for measurement purposes. The output values are each multiplied by a factor of 2 to improve the accuracy of subsequent noise measurements

The output file is created in the same location as the source file, and has the same name, but the extension will be "-hpfx2.bmp".

6 Analyse ColorChecker® image

Analysis of a BMP image of a ColorChecker® test card. The user controls a 6 x 4 array of measurement patches, and must align them over the individual colour patches such that they do not overlap into adjacent colours. The size and spacing of the measurement patches can be modified using keyboard keys (instructions are given in the program). The names and specifications of the colour patches are given in a text file.

Measurement results are sent to a text file, created in the same location as the source file, and with the same name but with an extra extension of ".txt".

7 Line and column scan

Analysis of any image BMP file. The user controls the position of horizontal and vertical cross-wires into parts of the picture to be analysed. The output results are not shown within the program.

Measurement results are sent to two text files, each created in the same location as the source file, and with the same name but with extra extensions of ".h.txt" and ".v.txt". Each file contains a listing of the pixel (or line) numbers, RGB digital values, and RGB analogue values. There is also a histogram tabulation of the values in the scan. These files can be directly imported into a spreadsheet, such as Excel, for further analysis or waveform plotting.

8 Measure pixel values

Analysis of any image BMP file. The user moves the position of a measurement point using the mouse. The RGB values at the mouse position are reported in the window title bar, as both digital and analogue values. The analogue value of the Y' (luma) equivalent is also given. The equation for deriving the luma signal is taken from a text file (supplied). The user can also increase the measurement area using the cursor keys, the size of the measurement area is also reported in the title bar.

Text files, containing data used by the programs, are:

- ***Chroma filter*** - Contains the coefficients for chroma sub-sampling and interpolation.
  Two filters are given, one which conforms to the specification limits in ITU-R BT.601 and ITU-R BT.709, and a much simpler, and faster, but less accurate one.

- ***Noise filter*** - Contains the coefficients for high-pass filtering to eliminate shading and vignetting.
- ***Test colours*** - Contains the names and colorimetric data for the colours of a ColorChecker® test card. Only the names are used in the programs.

Sample test files are supplied:

- ***Work file –*** ColorChecker®***.yuv***. Captured using a 'DVC ClipRecorder XTreme' data capture system. An image of a ColorChecker® test card captured during the testing of a camera.
- ***Work file –*** ColorChecker®***.yuv.rgb***. Generated from the above file, using programs #1 and then #2.
- ***Work file –*** ColorChecker®***.yuv-rgb.bmp***. Generated from the above file, using program #3.
- ***Work file –*** ColorChecker®***.yuv-rgb.bmp.txt***. Generated from the above file, using program #6
- ***Work file – Zone plates.yuv***. Captured using a 'DVC ClipRecorder XTreme' data capture system. An image of a ColorChecker® test card captured during the testing of a camera.
- ***Work file – Zone plates.yuv.bmp***. Generated from the above file, using program #3
- ***Work file – Zone plates.yuv-rgb***. Generated from the above file, using programs #1 and then #2.bmp. Generated from the above file, using program #3.
- ***Work file – Zone plates.yuv-rgb-hpfx2.bmp***. Generated from the above file, using program #5.
- ***Work file – Zone plates.yuv-rgb.bmp.h.txt (and .v.txt)***. Generated from Work file – Zone plates.yuv-rgb.bmp, using program #3.
- ***Work file – Noisy flat field.yuv***. Captured using a 'DVC ClipRecorder XTreme' data capture system. An image of a ColorChecker® test card captured during the testing of a camera.
- ***Work file – Noisy flat field.yuv.bmp***. Generated from the above file, using program #1 and then #2
- ***Work file – Noisy flat field.yuv-rgb.bmp***. Generated from the above file, using program #3
- ***Work file – Noisy flat field.yuv-rgb-hpfx2.bmp***. Generated from the above file, using program #5

Page intentionally left blank. This document is paginated for two sided printing

Annex 7: Example of the Presentation of Data

The following represents an example of camera test reporting, courtesy of Alan Roberts. It is recommended as a template for future camera testing.

The following contains results of the cameras tested so far.

Obviously there will be variations especially as new technologies are introduced to cameras. However the end result will always be the pictures and how well they are presented to the transmission chain for the audience.

Colorimetric and Resolution requirements of cameras

Alan Roberts

ADDENDUM 56: Tests and Settings on a Sony HDC1500R

Data for this section is taken from the handbook and examination of a production model (serial number 400152) of the Sony HDC1500R. The 1400R, 1450R, 1500R and 1550R belong to a family of system cameras built around a common design. The 1500R and 1400R have optical-fibre connection to the CCU and two SDI outputs, the 1550R and 1450R have triax cable connections and one SDI output. The 1400R and 1450R are cut-down versions, having no colour-temperature filter wheel and operate only at 1080/50i and 720/50P (EU types, the SY types run at 59.94 Hz), while the 1500R and 1550R have two filter wheels and operate at a wider range of standards, including 1080-progressive at 50 or 59.94 Hz, delivered via 2 BNC connections. Other differences are minor.

The cameras have three 1920 x 1080 CCDs and an F/1.4 optical block. The head weighs 4.5 kg, excluding lens and viewfinder, and consumes about 85 W at 12V DC if the head alone is powered.

It has many internal menus for setting the performance, with a structure very similar to that in the HDCAM camcorders. The menus can be accessed directly from the camera head, such that it can then be used without external controls, or via the usual remote control panels.

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 nominal range, and zero means no alteration to factory setting, not zero effect, and no scales are given. For each item, the factory setting is underlined, "BBC" settings are in the last column, where appropriate, and the reasons for the values are given in footnotes throughout the tables where necessary.

Where menus are hierarchical (i.e. one menu item opens another menu page), the items are inset.

"BBC" setting values are given for: Video {v}   Negative film {f}

Where different values are needed for these settings, they are marked e.g. thus: On{v} Off{f}. Note that the film settings are not intended to reproduce precisely the performance of any particular film stock, merely to give a ‘look’ that is representative of a generic film type.

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.

The results of tests are given after the menu settings.

A7.1. Menu Tables

TOP MENU

User	Go to daily routine settings, 5 pages that can be customised
User menu customise	Customise user menu pages
All	Go to all menu pages
Operation	Settings for shot-by-shot control
Paint	Settings that normally need lab facilities to control properly
Maintenance	Camera maintenance, usually best avoided
File	Load/save reference files etc
Diagnosis	Check status of hardware/software
Service	Keep out of here if at all possible

OPERATION MENUS

OPERATION01 VF DISPLAY

Item	*model*	*range*	*comment*	*BBC*
EX	All	On, Off		
Zoom	All	On, Off		
Disp	All	Left, Right		
Focus	All	On, Off	Only when a ‘serial’ lens is fitted	
ND	All	On, Off		
CC	1500, 1550	On, Off		
5600K	All	On, Off		
Iris	All	On, Off		
White	All	On, Off		
D.ext	All	On, Off		
Gain	All	On, Off		
Shutt	All	On, Off		
Batt	All	On, Off		
Return	All	On, Off		
Talk	All	On, Off		
Messag	All	All, Wrn, At, Off	Wrn=warnings+, AT=Auto+ higher	

OPERATION02 ! IND

Item	*model*	*range*	*comment*	*BBC*
ND	All	On, Off		
Normal	All	1, 2, 3, 4, 5	You can combine any of these	
CC	1500, 1550	On, Off	For 1500R/1550R only	
Normal	All	A, B, C, D, E	Combinations allowed	
White	All	On, Off		
Normal	All	P, A, B	Combinations allowed	
5600K	All	On, Off		
Normal	All	On, Off	Combinations allowed	
Gain	All	On, Off		
Normal	All	L, M, H	Combinations allowed	
Shutt	All	On, Off		
Normal	All	On, Off		
Fan	All	On, Off		
Normal	All	Auto1, Auto2, Min, Max		
Ext	All	On, Off		
Normal	All	On, Off		
Format	All	On, Off		
Normal	1500, 1550	59.94i, 29.97psf, 50i, 25psf, 24psf, 23.98psf, 59.94p, 50p	This is the major difference between the various models	
	1400 JN3/JN4, 1450 UC7	59.94i, 59.94p		
	1400 CED/E33, 1450 CED	50i, 50p		

OPERATION03 VF MARKER

Item	*model*	*range*	*comment*	*BBC*
Marker	All	On, Off		
	All	White, Black, Dot		
Center	All	On, Off	1=full cross, 2=centre hole, 3=centre, 4=centre with hole	
	All	1, 2, 3, 4		
Safety zone	All	On, Off		
	All	80, 90, 92.5, 95%		
Effect	All	On, Off, Focus	Focus available only for Focus Assist	
Aspect	All	On, Off		
	All	16:9, 15:9, 14:9, 13:9, 4:3		14:9
Mask	All	On, Off		
	All	0~12~15		
Safety	All	On, Off Area		
	All	80, 90, 92.5, 95%		

OPERATION04 VF DETAIL

Item	*model*	*range*	*comment*	*BBC*
VF Detail	All	On, Off		
	All	25~100%		
Crisp	All	-99~0~+99		
Frequency	All	9M, 14M, 18M		
FAT Mode	All	On, Off		
Flicker	All	On, Off		
Zoom link	All	0, 25, 50, 75, 100%		
Color detail	All	On, Off		
Peak color	All	On, Off		
	All	Blue, Red, Yellow		
Chroma level	All	100, 50, 25, 0%		

OPERATION05 FOCUS ASSIST

item	*model*	*range*	*comment*	*BBC*
Indicator		On, Off, Effect	Effect applies to Effect, VF Marker	
Mode		Box, B&W, Col		
		Bottom, Left, Top, Right		
Level		1~3~5		
	All	Quick, Smooth		
Gain	All	0~50~99		
Area Marker	All	On, Off, Aspect	Aspect applies to Safety, VF Marker	
Size	All	Small, Middle, Large		
Position	All	Left, Center, Right		
Position H	All	0~50~99		
Position V	All	0~50~99		

OPERATION06 ZEBRA

item	*model*	*range*	*comment*	*BBC*
Zebra	All	On, Off		
	All	1, 2, 1&2		
Zebra1 level	All	50~70~109%		
Width	All	0~10~30%		
Zebra2	All	50~100~109%		

OPERATION07 CURSOR

item	*model*	*range*	*comment*	*BBC*
Cursor	All	On, Off		
	All	White, Black, Dot		
Box/Cross	All	Box, Cross		
H Position	All	0~50~99		
V Position	All	0~50~99		
Width	All	0~50~99		
Height	All	0~50~99		

OPERATION08 VF OUT

item	*model*	*range*	*comment*	*BBC*
VF out	All	Color, Y, R, G, B	Option fixed when HDLA used	
Ret mix VF	All	On, Off		
Mix direction	All	Main, Ret		
Mix VF mode	All	Y-mix, Wire(W), Wire(B)		
Mix VF level	All	0~80%		
VF scan	All	16:9, 4:3		

OPERATION09 SWITCH ASSIGN1

item	*model*	*range*	*comment*	*BBC*
Gain				
L	All	-3, 0, 3, 6, 9, 12dB		-3[1]
M	All	-3, 0, 3, 6, 9, 12dB		0
H	All	-3, 0, 3, 6, 9, 12dB		+6
Assignable	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2, VF detail, Mix VF, 5600K, Fan max, D.Extender		
Assignable	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod VF detail, Mix VF, 5600K, Fan max, D.Extender		
RE.rotation	All	Std, Rvs	Orientation of Menu Sel knob	

OPERATION10 SWITCH ASSIGN2

item	*model*	*range*	*comment*	*BBC*
Lens VTR S/S	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2		
	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod		
Front ret 1	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2, D.extender		
	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod, D.extender		
Front ret 2	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2, D.extender		
	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod, D.extender		
Handle sw 1	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2, D.extender		
	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod, D.extender		
Handle sw 2	JN3, JN4, SYL, UC7	Off, Return1 sw, Return2 sw, Incom1, Incom2, Zoom(W)		
	CED, E33	Off, Return1 sw, Return2 sw, Eng, Prod, Zoom(W)		
Zoom speed	All	0~20~99		
Hkct income mic	JN3, JN4, SYL, UC7	Off, Incom1, Incom2		
	CED, E33	Off, Eng, Prod		

[1] Noise levels are rather high, low gain setting should be used wherever possible

OPERATION11 HEAD SET

item	*model*	*range*	*comment*	*BBC*
Intercom1 mic	All	Dynamic, Carbon, Manual		
Level	All	-60,-50,-40,-30,-20dB	Not available for Dynamic or Carbon	
	All	-6, 0, +6dB	Gain control	
Power	All	On, Off	Not available for Dynamic or Carbon	
Unbal	All	On, Off	Not available for Carbon	
Intercom2 mic	All	Dynamic, Carbon, Manual		
Level	All	-60,-50,-40,-30,-20dB	Not available for Dynamic or Carbon	
	All	-6, 0, +6dB	Gain control	
Power	All	On, Off	Not available for Dynamic or Carbon	
Unbal	All	On, Off	Not available for Carbon	

OPERATION12 INTERCOM LEVEL

item	*model*	*range*	*comment*	*BBC*
Side tone	All			
Intercom1	All	MU, 1~50~99		
Intercom2	All	MU, 1~50~99		

OPERATION13 RECEIVE SEL1

item	*model*	*range*	*comment*	*BBC*
Intercom1 receive select	All	Separate, Mix		
Intercom	JN3, JN4, SYL, UC7	Left, Right, Both		
Eng	CED, E33	Left, Right, Both		
Prod	CED, E33	Left, Right, Both		
PGM1	All	Left, Right, Both		
PGM2	All	Left, Right, Both		
Tracker	All	Left, Right, Both		

OPERATION14 RECEIVE SEL2

item	*model*	*range*	*comment*	*BBC*
Intercom2 receive select	All	Separate, Mix		
Intercom	JN3, JN4, SYL, UC7	Left, Right, Both		
Eng	CED, E33	Left, Right, Both		
Prod	CED, E33	Left, Right, Both		
PGM1	All	Left, Right, Both		
PGM2	All	Left, Right, Both		
Tracker	All	Left, Right, Both		

OPERATION15 RECEIVE SEL3

item	*model*	*range*	*comment*	*BBC*
Tracker receive select	All	Separate, Mix		
Intercom	JN3, JN4, SYL, UC7	Left, Right, Both		
Eng	CED, E33	Left, Right, Both		
Prod	CED, E33	Left, Right, Both		
PGM1	All	Left, Right, Both		
PGM2	All	Left, Right, Both		

OPERATION16 RECEIVE SEL4

item	*model*	*range*	*comment*	*BBC*
Earphone receive select	All	Separate, Mix		
Intercom	JN3, JN4, SYL, UC7	Left, Right, Both		
Eng	CED, E33	Left, Right, Both		
Prod	CED, E33	Left, Right, Both		
PGM1	All	Left, Right, Both		
PGM2	All	Left, Right, Both		

OPERATION17 OPERATOR FILE

item	*model*	*range*	*comment*	*BBC*
Read (MS-CAM)	All		Execute, copy from stick to camera	
Write (Cam-MS)	All		Execute, copy from camera to stick	
Preset	All		Execute, reset to internal memory file	
File ID	All		Max 16 characters	
Cam mode	All		Display only	
Date	All		Display only	

OPERATION18 LENS FILE

item	*model*	*range*	*comment*	*BBC*
File	All	1~17	16 files normally, 17 with a ‘serial’ lens	
	All		Lens file name, non-‘serial’ lenses	
	All		Stop value, non-‘serial’ lens	
Center marker	All		Set the image centre point	
H.Pos	All	-20~0~+20		
V.Pos	All	-20~0~+20		
Store	All		Execute	

PAINT

PAINT01 SW STATUS main controls

item	*model*	*range*	*comment*	*BBC*
Flare	All	On, Off		On
Gamma	All	On, Off		On
Blk gamma	All	On, Off		On{v} Off{f}
Knee	All	On, Off		On{v} Off{f}
White clip	All	On, Off		
Detail	All	On, Off		On{v} Off{f}
Lvl dep	All	On, Off		
Skin dtl	All	On, Off		
Matrix	All	On, Off		On

PAINT02 VIDEO LEVEL

item	*model*	*range*	*comment*	*BBC*
White	All	-99~+99	RGB values	
Black	All	-99~+99	RGBM values	
Flare	All	-99~+99	RGB values	
Gamma	All	-99~+99	RGBM values	
V mod	All	-99~+99	RGBM values	
Flare	All	On, Off		
V.mod	All	On, Off		
D.shad	All	On, Off		
Test	All	Off, Saw, 3step, 10step		

PAINT03 COLOR TEMP

item	*model*	*range*	*comment*	*BBC*
White	All	-99~+99	RGB values	
Auto white bal	All		Execute, press Enter	
Color temp	All	0~3200~65535K		
Balance	All	-99~+99		
Master	All	-3.0~0.0~+12.0dB		

PAINT04 GAMMA

item	*model*	*range*	*comment*	*BBC*
Level	All	-99~+99	RGBM values	0
Coarse	All	0.35~0.45~0.90		0.45
Table	All	Standard, Hyper	Same choices as for other Sonys	Standard {v}, Hyper {f}
Standard	All	1, 2, 3, 4, 5, 6, 7	1=camcorder, 2=4.5x, 3=3.5x, 4=SMPTE240M, 5=ITU709, 6=BBC0.4, 7=5x 709	6 {v}
Hyper	All	1, 2, 3, 4	1=325%(100%), 2=460%(100%), 3=325%(109%), 4=460%(109%)	1~4 {f}[1]
Gamma	All	On, Off		
Test	All	Off, Saw, 3step, 10step		

PAINT05 BLACK GAMMA

item	*model*	*range*	*comment*	*BBC*
Level	All	-99~+99	RGBM values	
Range	All	Low, L.mid, H.mid, High		
	All	On, Off		Off[2]
Test	All	Off, Saw, 3step, 10step		

PAINT06 SATURATION

item	*model*	*range*	*comment*	*BBC*
Saturation	All	-99~0~+99		
	All	On, Off		
Low key sat	All	-99~0~+99		
Range	All	Low, L.mid, H.mid, High		
	All	On, Off		
Test	All	Off, Saw, 3step, 10step		

PAINT07 KNEE highlight compression

item	*model*	*range*	*comment*	*BBC*
Knee point	All	-99~+99	RGBM values	
Knee slope	All	-99~+99	RGBM values	
Knee	All	On, Off		
Knee max	All	On, Off		
Knee sat	All	-99~0~+99		
		On, Off		
Auto knee	All	Off, Auto		
Point limit	All	-99~+99		
Slope	All	-99~+99		
ABS	All		Toggle between relative and absolute values	

[1] Hyper gamma curves 1 and 3 handle 1.5 stops, curves 2 and 4 handle 2.3 stops. Curve 1 and 2 are suitable for line/as line use in that they clip at 100%, curves 3 and 4 use the full video signal range and thus are suitable only when postproduction

[2] Camera noise levels are rather high, use of Black Gamma, while revealing detail near black, will emphasise noise

PAINT08 WHITE CLIP

item	*model*	*range*	*comment*	*BBC*
W clip	All	-99~+99	RGBM values	
	All	On, Off		
ABS	All		Toggle between relative and absolute values	

PAINT09 DETAIL1   Sharpening only

item	*model*	*range*	*comment*	*BBC*
Detail	All	On, Off		On {v}, Off {f}
Level	All	-99~0~+99		0[1]
Limiter M	All	-99~0~+99		0
Limiter wht	All	-99~0~+99		0
Limiter blk	All	-99~0~+99		0
Crisp	All	-99~0~+99		0
Lvl dep	All	-99~0~+99		0
ABS	All		Toggle between relative and absolute values	

PAINT10 DETAIL2   harpening only

item	*model*	*range*	*comment*	*BBC*
H/V ratio	All	-99~0~+99		0
Freq	All	-99~0~+99		+99
Mix ratio	All	-99~0~+99		0
Knee aperture	All	-99~0~+99		0
ABS	All		Toggle between relative and absolute values	

PAINT11 SKIN DETAIL   Softening only

item	*model*	*range*	*comment*	*BBC*
Skin dtl	All	On, Off		
Skin gate	All	Off, 1, 2, 3, Mat	Mat only if Multi-Matrix Gate is on	
ABS	All		Toggle between relative and absolute values	
Ch sw	All	On, Off	3 separate skin gates	
Hue	All	Auto	Execute	
Phase	All	0~359	Gate 1, 2, 3	
Width	All	0~29~90	Gate 1, 2, 3	
Sat	All	-99~-89~+99	Gate 1, 2, 3	
Level	All	-99~0~+99	Gate 1, 2, 3	

[1] Setting level zero does not mean no effect, in all cases this only means the factory default value

PAINT12 USER MATRIX

item	*model*	*range*	*comment*	*BBC*
R-G	All	-99~0~+99		
R-B	All	-99~0~+99		
G-R	All	-99~0~+99		
G-B	All	-99~0~+99		
B-R	All	-99~0~+99		
B-G	All	-99~0~+99		
Matrix	All	On, Off		
Preset	All	On, Off		
	All	SMPTE240M, ITU709, SMPTEwide, NTSC, EBU, ITU601		ITU-709
User	All	On, Off		
Multi	All	On, Off		

PAINT13 MULTI MATRIX

item	*model*	*range*	*comment*	*BBC*
Phase	All	0, 23, 45, 68, 90, 113, 135, 158, 180, 203, 225, 248, 270, 293, 315, 338	Colour axis to operate on	
Hue	All	-99~0~+99		
Sat	All	-99~0~+99		
All clear	All		Execute	
Gate	All	On, Off, Skin	Skin shows if Gate of Skin Dtl is on	
Matrix	All	On, Off		
Preset	All	On, Off		
	All	SMPTE240M, ITU709, SMPTEwide, NTSC, EBU, ITU601		
User	All	On, Off		
Multi	All	On, Off		

PAINT14 SHUTTER

item		*model*	*range*	*comment*	*BBC*
Shutter		All	On, Off		
	59.94i	see comment	1/100, 1/125, 1/250. 1/500, 1/1000, 1/2000	Defaults to 1/100 for JN3, JN4, SYL, UC7 models, 1/60 for CED, E33 models.	
	50i		1/60 1/100, 1/125, 1/250. 1/500, 1/1000, 1/2000		
	29.97psf		1/40, 1/60, 1/125, 1/250. 1/500, 1/1000, 1/2000		
	25psf		1/33, 1/50, 1/125, 1/250. 1/500, 1/1000, 1/2000		
	24/23.98psf		1/32, 1/48, 1/96, 1/125, 1/250. 1/500, 1/1000		
	59.94P		1/125, 1/250. 1/500, 1/1000, 1/2000	1400 and 1450 don't do all these formats	
	50p		1/60, 1/125, 1/250. 1/500, 1/1000, 1/2000		
ECS freq	59.94i	see comment	60~4300 Hz	1400 and 1450 don't do all these formats	
	50i		50~4700Hz		
	29.97psf		30~2700Hz		
	25psf		25~2300Hz		
	24/23.98psf		24~2200Hz		
	59.94P		59.96~4600Hz		
	50p		50.03~4600Hz		

PAINT15 NOISE SUP

item	*model*	*range*	*comment*	*BBC*
Noise sup	All	0~100%		
	All	On, Off		

PAINT16 SCENE FILE

item	*model*	*range*	*comment*	*BBC*
1	All		Select scene file or factory STANDARD. Always load STANDARD first when setting up a camera. Open box indicator to read from camera, filled box indicator to read from stick.	
2	All			
3	All			
4	All			
5	All			
Standard	All		Back to standard PAINT data	
Read (MS-cam)	All		Load 5 scene files from stick	
Write (Cam-MS)	All		Save 5 scene files to stick	
File ID	All		16 characters	
Cam code	All		Display only	
Date	All		Display only	

MAINTENANCE

MAINTENANCE01 AUTO SETUP

item	*model*	*range*	*comment*	*BBC*
Auto black	All		Execute	
Auto white	All		Execute	
Auto level	All		Execute	
Auto white shading	All		Execute	
Auto black shading	All		Execute	
Test	All	Off, Saw, 3step, 10step		

MAINTENANCE02 WHITE SHADING

item	*model*	*range*	*comment*	*BBC*
V saw	All	-99~+99	RGB values	
V para	All	-99~+99	RGB values	
H saw	All	-99~+99	RGB values	
H para	All	-99~+99	RGB values	
White	All	-99~+99	RGB values	
Auto white shading	All	Execute		
White shad mode	All	RGB, RB		
3d white shad	All	On, Off		

MAINTENANCE03 BLACK SHADING

item	*model*	*range*	*comment*	*BBC*
V saw	All	-99~+99	RGB values	
V para	All	-99~+99	RGB values	
H saw	All	-99~+99	RGB values	
H para	All	-99~+99	RGB values	
Blk set	All	-99~+99	RGB values	
Black	All	-99~+99	RGBM values	
Master gain	All	-3, 0, 3, 6, 9, 12dB		
Auto black shading	All		Execute	
2d black shad	All	On, Off		

MAINTENANCE04 OHB MATRIX

item	*model*	*range*	*comment*	*BBC*
Phase	All	0, 23, 45, 68, 90, 113, 135, 158, 180, 203, 225, 248, 270, 293, 315, 338	Degrees around the hue circle	
Hue	All	-99~0~+99		
Sat	All	-99~0~+99		
All clear	All		Execute, reset data	
OHB matrix	All	On, Off		
Matrix	All	On, Off		On

MAINTENANCE05 AUTO IRIS

item	*model*	*range*	*comment*	*BBC*
Auto iris	All	On, Off		
Window	All	1, 2, 3, 4, 5, 6	1=low 2/3, 2=mid, 3=mid 2/3, 4=full, 5=low mid, 6=high 2/3	
Override	All	-99~+99		
Iris level	All	-99~0~+99		
APL ratio	All	-99~+65~+99		
Iris gain	All	-99~0~+99		
Iris close	All	On, Off		

MAINTENANCE06 MIC GAIN

item	model	range	comment	BBC
Mic 1	All	20, 30, 40, 50, 60dB	Relevant only without MCP/OCP	
Mic 2	All	20, 30, 40, 50, 60dB		

MAINTENANCE07 UP TALLY

item	model	range	comment	BBC
Tally brightness	All	0~50~100		
Number brightness	All	0~50~100		
Camera number	All	1~96		
Number display	All	On, Off, Auto		

MAINTENANCE08 CALL/TALLY

item	model	range	comment	BBC
CCU call	All	On, Off		
Cam call	All	On, Off		

MAINTENANCE09 OUTPUT FORMAT

item	model	range	comment	BBC
Current	All		Show current format	
Active line	All	1080, 720		
	All		For format options see OPERATION02 ! LED	

MAINTENANCE10 DOWN CONVERTER

item	model	range	comment	BBC
Output signal	All	Main, Ret, VF		
Aspect	All	SQ, EC		

MAINTENANCE11 TEST OUT

item	model	range	comment	BBC
Output	All	SD sync, HD sync, VF, VBS		
Pwr save	All			
VBS-out	All			
Character	All	On, Off		
Gain	All	-127~0~+127		
Chroma	All	-127~0~+127		
Setup	JN3, JN4, SYL, UC7	On, Off	Only when output format is NTSC	
HD-sync-out	All			
V phase	All	-127~0~+127		
H phase	All	-127~0~+127		

MAINTENANCE12 SDI 2 OUT (1500)

item	*model*	*range*	*comment*	*BBC*
Output	1500	Main, VF, Link-B, Ret, SD-SDI	SD-SDI output as selected in MAINTENANCE10	
Pwr save				
Character		On, Off	Not on VF or Link-B	
EMB audio		On, Off	Embedded audio	
		1-Mic, 2-Mic2, 3-AES1, 4-AES2	Display for Main or Link-B	
		1-PGM1, 2-PGM2, 3-Eng, 4-Prod	Display for VF, Ret or SD-SDI	

MAINTENANCE12 SDI OUT (1550, 1400, 1450)

item	*model*	*range*	*comment*	*BBC*
Output	1550, 1400, 1450	Main, VF, Ret, SD-SDI		
Pwr save				
Character		On, Off	Not on VF	
EMB audio		On,Off	Embedded audio	
		1-Mic, 2-Mic2, 3-AES1, 4-AES2	Display for Main	
		1-PGM1, 2-PGM2, 3-Eng, 4-Prod	Display for VF, Ret or SD-SDI	

MAINTENANCE13 POWER SAVE

item	*model*	*range*	*comment*	*BBC*
SDI-2 out	1500	Pwr save, Active		
SDI out	1550, 1400, 1450	Pwr save, Active		
Down converter	All	Pwr save, Active		

MAINTENANCE14 TRUNK

item	*model*	*range*	*comment*	*BBC*
Trunk	All	On, Off		
IF	All	232c, 422A		

MAINTENANCE15 GENLOCK (1500, 1550)

item	*model*	*range*	*comment*	*BBC*
Reference	1500, 1550		Display only, sync condition	
Genlock			Shown only when there's no CCU	
Status				
Format				
Phase				
V		-1024~0~+1023		
HD H		-1700~0~+1700		
SD H		-1024~0~+1023		

MAINTENANCE16 DATE

item	*model*	*range*	*comment*	*BBC*
Date/time	All	yyyy/mm/dd hh:mm	2000 to 2099, a bit optimistic!	

MAINTENANCE17 BATTERY ALARM

item	*model*	*range*	*comment*	*BBC*
Before end	All	11.5~17.0V		
End	All	11.0~11.5V		

MAINTENANCE18 OTHERS 1

item	*model*	*range*	*comment*	*BBC*
Fan mode	All	Off, Auto1, Auto2, Min, Max	Auto1=normal, Auto2=slow	
Cam bars	All	On,Off		
V dtl creation	All	NAM, G, R+G, Y		
Dtl HV mode	All	H/V, V		
Test 2 mode	All	3step, 10setp		
White setup mode	All	AWB, A.lvl		
ALAC	All	Auto, Off	Auto starts process, chromatic aberration correction, see the manual for details	

MAINTENANCE19 OTHERS 2

item	*model*	*range*	*comment*	*BBC*
Date type	All	1 Y/Mn/D, 2 Mn/D, 3 D/M/Y, 4 D/M, 5 M/D/Y, 6 M/D	Y=year, Mn=month as number, M=month as text, D=day	
Filter wht mem	All	On, Off	Store white balance for filter positions	
F no. disp	All	Control, Return	Where the iris data comes from	

MAINTENANCE20 OPTION KEY

item	*model*	*range*	*comment*	*BBC*
Read (MS-cam)	All		Read Install key from memory stick	
Installed option	All		Display of installed option cards	

FILE

FILE01 OPERATOR FILE

item	*model*	*range*	*comment*	*BBC*
Read (MS-cam)	All		The usual stuff, doesn't affect pictures	
Write (Cam-MS)	All			
Preset	All			
Store preset file	All			
File ID	All		Maximum 16 characters	
Cam code	All		Display only	
Date	All		Display only	

FILE02 SCENE FILE picture stuff

item	*model*	*range*	*comment*	*BBC*
1	All		The usual stuff, all picture-related	
2	All			
3	All			
4	All			
5	All			
STORE	All			
Read (MS-cam)	All			
Write (cam-MS)	All			
File ID	All		Maximum 16 characters	
Cam code	All		Display only	
Date	All		Display only	

FILE03 REFERENCE FILE

item	*model*	*range*	*comment*	*BBC*
Store file	All		Store current settings as Reference	
Standard	All		Reset to Standard	
All preset	All		Back to factory settings	
Read (MS-cam)	All			
Write (cam-MS)	All			
File ID	All		Maximum 16 characters	
Cam code	All		Display only	
Date	All		Display only	

FILE04 LENS FILE lens corrections

item	*model*	*range*	*comment*	*BBC*
Store file	All			
No.	All	<u>1</u>~17	Only 16 for non'serial' lenses	
Name	All		Changeable only for non'serial' lens	
F No	All	F1.0~<u>F1.7</u>~F3.4	Changeable only for non'serial' lens	
Center marker	All			
H Pos	All			
V Pos	All			
Store	All			

FILE05 OHB FILE sensor file

item	*model*	*range*	*comment*	*BBC*
Store file	All		Store offset data for CCDs	

FILE06 FILE CLEAR

item	*model*	*range*	*comment*	*BBC*
Preset operator	All			
Reference (all)	All			
10 sec clear	All	On, Off		
OHB white shad (all)	All			
OHB white shad (3D)	All			
OHB black shad	All			
OHB ND shad	All			
OHB matrix	All			
M.S. format	All		Format the Memory Stick	

DIAGNOSIS

DIAGNOSIS01 OPTICAL LEVEL Indicators only, no options

item	*model*	*range*	*comment*	*BBC*
CCU-cam	All	Green, Yellow, Red, NG, No signal	Only when CCU connected	
Cam-CCU	All			

DIAGNOSIS02 BOARD STATUS Indicators only, no options

item	*model*	*range*	*comment*	*BBC*
OHB	All			
DPR	All			
VDA	All			
DAP	All			
AU	All	OK, NG		
AT	All			
PS	All			
SDI	1500, 1400			
TR	1500, 1400			

DIAGNOSIS03 PDL VERSION Indicators only, no options

item	*model*	*range*	*comment*	*BBC*
TD	All			
VDA	All			
DAP	All			
AT	All	Vx.xx		
SDI	All			
TR	1550, 1450			
DPR	All			
HKCT	All		Only when HKC-T1500 installed	

DIAGNOSIS04 ROM VERSION Indicators only, no options

item	*model*	*range*	*comment*	*BBC*
AT	All			
Panel	All	Vx.xx	Only with HDLA attached	
HKCT	All		Only when HKC-T1500 installed	

DIAGNOSIS05 SERIAL NO Indicators only, no options

item	*model*	*range*	*comment*	*BBC*
Model	All	HDCxxxxR		
No	All			
Option	All		Shows what options are installed	

A7.2. Measurements

All measurements were made at BBC R&D, using a Sony 32" CRT Grade 1 HDTV monitor and a digital waveform monitor. Frame files were grabbed via HDSDI for software analysis. Importing recordings into editing software is unreliable because the decoding and transcoding is not fully specified. The lens was a Canon HJ22x7.6.

A7.2.1 Gamma and Headroom range

The camera has seven 'standard' gamma curves and four 'hyper' gammas. Colour performance, with the ITU.709 gamma curve, was good, although a little over-saturated.

The Hyper-gamma curves are those of the HDWF900R and other similar Sony cameras, providing for filmlike transfer over either 325% or 460% headroom, delivered into either 100% or 109% video signal range. They are known to perform well; there was no need to examine them in this camera.

The Standard curves, also, are those of other cameras, with a few additions. The most important curves are numbers 6 and 7 in the table, ITU.709 and BBC0.4. Since this is a HDTV camera, the 709 curve should be regarded as the normal option, unless there is a specific need to change it to achieve specific picture performance. Since the Hyper-gammas handle headroom well, there is little need to explore the knee function, using Standard curves. Knee curves should be able to cope with about 2 stops of over-exposure.

A7.2.2 Resolution

Resolution was tested using a test card of circular zone plate patterns, calculated for 1920 x 1080 standard. The zone plate presents a spatial map of all the frequencies the camera should have to deal with, dc and low frequencies in the middle of each pattern, rising to the Nyquist limits horizontally and vertically. The test chart has sinusoidal modulation to avoid sampling problems, and has patterns for luminance, chrominance, R, G and B. Only the luminance pattern is presented here, the other patterns revealed no surprises.

A7.2.2.1 Resolution at 1080-line

With detail enhancement switched off, the results for 1080-line interlace are as expected. Horizontal resolution droops gracefully towards the edge of the pattern, as it should do, due to the effect of the optical horizontal low-pass filter. Vertical resolution also falls, but this time due to the line-pairing implicit in interlaced scanning. There are no null zones or alias patterns visible at all.

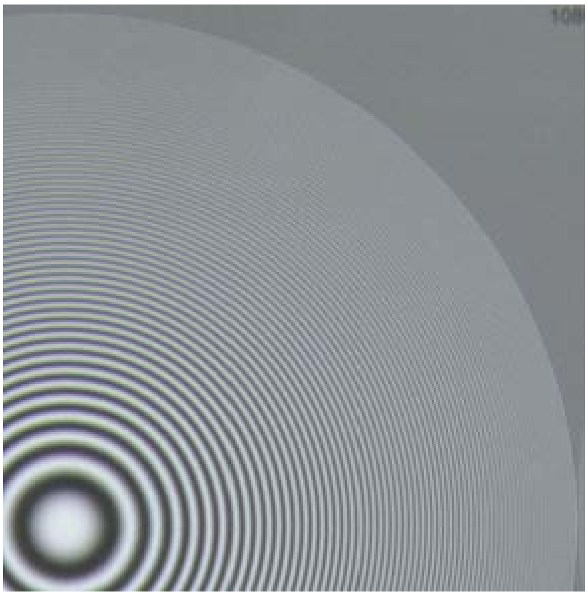


Figure 1: Resolution, 1080i, detail off

Performance in 1080-line progressive is also as expected, with no null zones or aliasing. There is more vertical resolution, but horizontal and vertical resolutions are now inter-changeable, indicating that the optical spatial filtering is symmetrical, as it should be.

As a result, detail enhancement produces no unexpected effects. The values given in the menus for detail enhancement are similar to those developed for the HDWF900R, and produce clean images without overshooting (ringing) edges, although there is a 'grittiness' at higher frequencies.

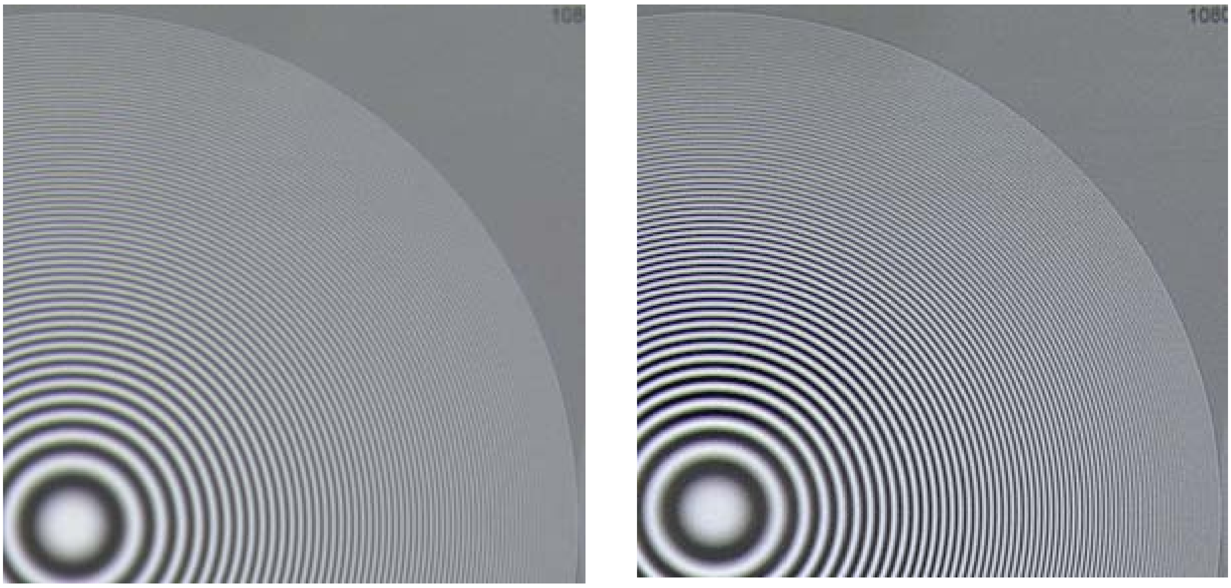


Figure 2: Resolution, 1080 interlaced
(a) detail off **(b) detail on**

A7.2.2.1 Resolution at 720p

There is faint aliasing in the picture, both horizontally and vertically. This is inevitable in any camera, since the conversion to 720p is a standards-conversion, which cannot be done satisfactorily in any camera at an economic price.

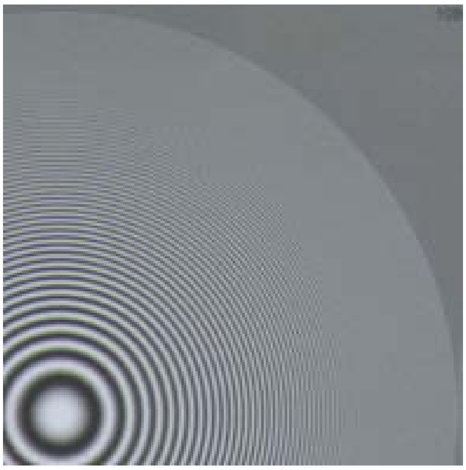


Figure 3: Resolution, 720p

Resolution up to the limits (1280x720) is clean, with low-level aliasing above. Vertical aliasing is less well suppressed than horizontal, hinting that the vertical down-sampling filter has fewer terms (contributions from adjacent lines) than has the horizontal filter. This is not unusual, better vertical filtering would result in a greater camera delay, which could be unacceptable in live programme-making.

The detail enhancement settings for 1080 work well at 720p.

A7.2.3 Noise

Noise was measured by exposing the camera to an evenly illuminated white card, and exposure adjusted to get 4 luma values between 10% and 100%. Noise suppression was switched off for this test. Gain was set to +6dB, and the results compensated accordingly in the calculations, therefore they represent the noise levels at 0dB gain. The grabbed frames were processed with a high-pass filter to remove any residual shading effects. Vignetting was avoided by adjusting the lighting level such that the extremes of the aperture range were not used.

The plot of measured noise versus signal level for 1080p shows that noise in the middle range (where the slope of the gamma curve is unity) is at about -43dB, which is adequate but a rather disappointing. This was confirmed by direct observation during the tests, both off-screen and on the waveform monitor. The general shapes of the curves are as expected, since the primary source of noise is the analogue circuitry of the sensor and pre-amplifiers, which is non-linearly amplified by the gamma-corrector. Blue noise is a few decibel worse than red or green, this is normal.

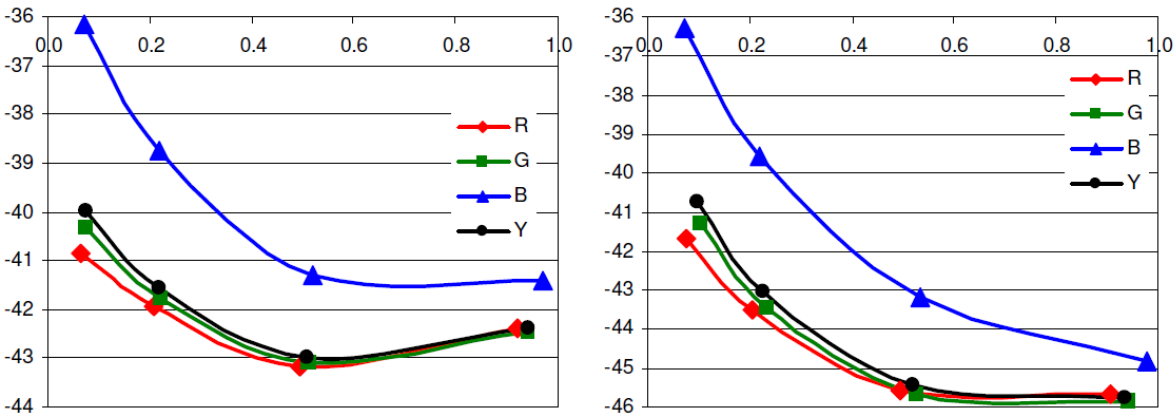


Figure 4: Noise levels
(a) 1080p (b) 720p

Noise at 720p is about 2dB lower than for 1080p, primarily to the reduced bandwidth.

The noise levels are surprisingly high for a camera with full-resolution ⅔" CCD sensors. Noise suppression can reduce the levels by about 3dB, but there will inevitably be some affect on resolution due to the spatial filtering involved. Studio cameras should normally be capable of noise levels about 10dB better than this, and these high levels mean that the maximum exposure range is only about 10 stops, and that high gain settings should be avoided wherever possible.

A7.2.4 Iris Diffraction and Chromatic Aberration

The camera has an adaptive chromatic aberration correction system, which works only horizontally. The lens used for the tests was not of the type which provides the camera with sufficient data to correct aberrations, but over the normal range of iris aperture settings (closing to about F/8), no corner aberrations were noticed.

A7.2.5 Conclusion

The HDC1500R performs well, but is rather noisy. There is no reason to suppose that the results would be any different for the 1550R, 1400R or 1450R.