

EBU - Tech 3335 : **Methods of measuring the imaging performance of television cameras for the purposes of characterisation and setting**

Alan Roberts, June 2016

SUPPLEMENT 23: Assessment of a Pacific PHD-02XP camera

Tests have been conducted in line with EBU R.118. This document is a report of the results of the tests defined in Tech3335 and is not an endorsement of the product.

This is a report on tests carried out on a Pacific mini-camera, model PHD-02XP-GSFG-EU, serial number C6 0001. From its early serial number and the fact that the manual document says 'Preliminary', this may well be a prototype and thus the performance of later cameras could be different.

It has a single Bayer-patterned CMOS sensor of nominal $\frac{1}{3}$ " dimensions and 2.1 Mpixels. Thus the photo-sites are spaced at $2.75\mu\text{m}$, and the active area must be about 30% that of a conventional $\frac{2}{3}$ " camera, about $1\frac{3}{4}$ stops below. It can operate in a variety of formats: 1920x1080p at 60/59.94/50fps, 1920x1080i at 60/59.94/50/30/29.97/25/24/23.97fps, 1280x720p at 60/59.94/50fps. It is unclear whether the HDSDI output is 8- or 10-bit, although the performance indicates 8-bit.

The integral lens is a 20:1 zoom, 4.7 to 94mm, F/1.6 to F/3.5 at the telephoto end.

Being a mini-camera, it has no controls or viewfinder. The connectors are a range of unmarked miniature single-in-line sockets, for power, control keyboard, serial data, alarm outputs, audio in, video in/out, genlock in, and a sub-miniature coaxial socket for HDSDI.

Control is by custom software via serial data using VISCA or PELCO-D protocol, a Windows version was used for the tests. Some of the camera functions can be controlled via an on-screen menu.

The camera body is 50x60x88mm overall and weighs about 290 grams. Power consumption is 7.8W at 6.5~13.5volts DC.

The camera performance was mixed, and motion portrayal is severely affected by the rolling shutter.

Tests were made according to EBU Tech.3335, and the results establish that the camera belongs in HD Tier SP.

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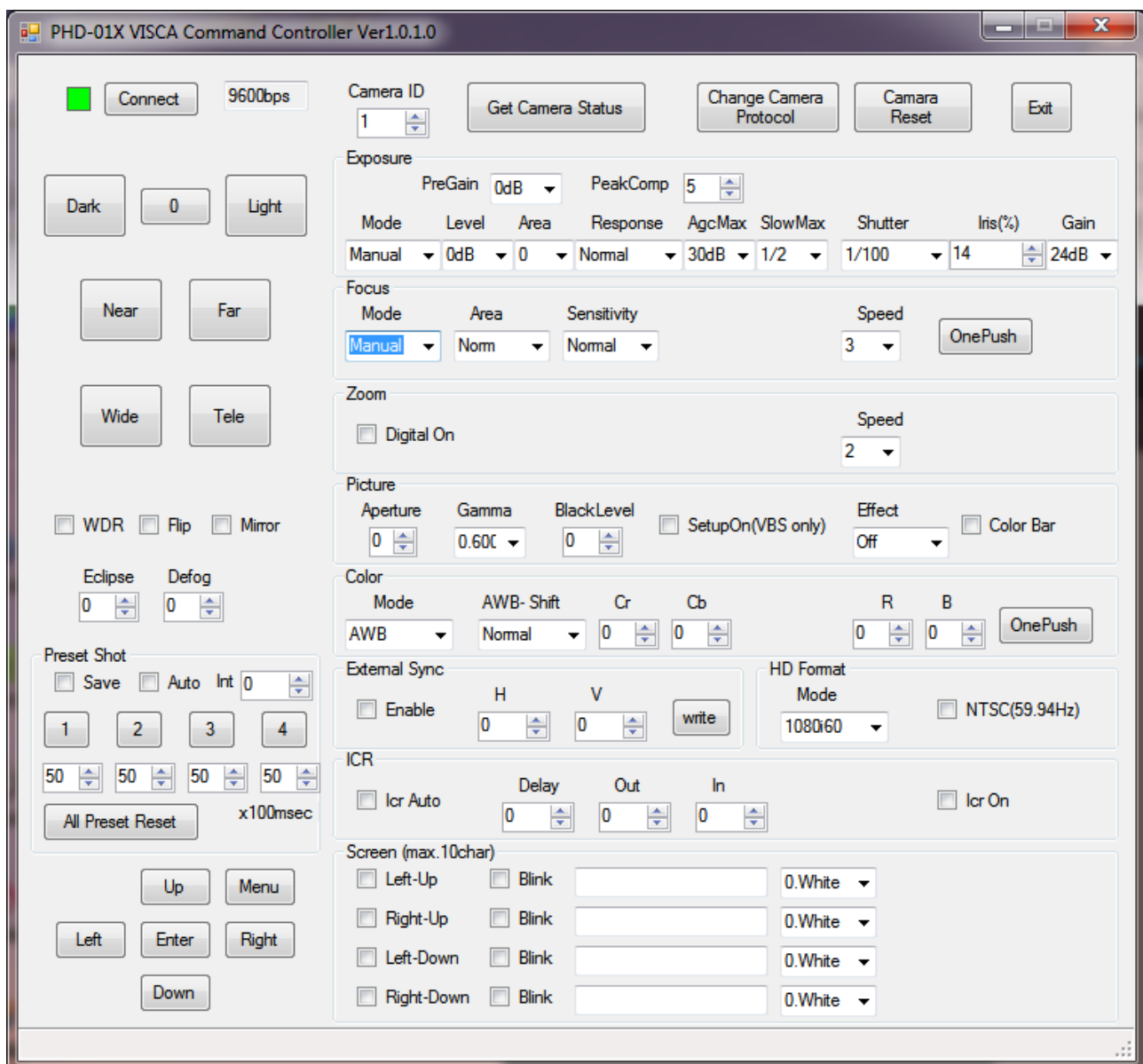
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Measurement results are given in section 3, after the menus. Measurements were made according to the procedures set out in EBU Tech.3335.

This listing of the menus and contents is complete, but this should not be used as an excuse for not reading the manuals. Items which have significant effect on picture quality are highlight, my preference values are given in the right-hand column

The software has a single plane :



... although there is a preliminary dialog to set the comms port. I spent quite a while trying to find out how to set the comms port, because the preliminary dialog was concealed behind the main plane. There is no reason why this could not be incorporated into the main plane.

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1. Menu contents

Across the top			
Item	Range	Description	Pref
Connect		Connect/disconnect the camera	
bps setting			
Camera ID	1 ~ 100		
Get Camera Status		Load up parameters from chosen camera	
Change Camera Protocol			
Camera Reset		Factory settings	
Exit		Close the software	
Exposure			
Item	Range	Description	
Dark		Big buttons for single-control exposure, combines iris and gain, not tested	
0			
Bright			
PreGain	0, -6dB	Sensitivity change	0
PeakComp	0 ~ 5 ~ 16	Available only in Auto mode	
Mode	Auto, Manual, Shut-P, Iris-P, Manual2		
Level	-6 ~ 0 ~ +6dB	1/2dB step offset for Auto	
Area	0 ~ 11		
Response	Fast, Normal, Slow		
AgcMax	0, 3, 6, 12, 17, 21, 26, 30, 36, 42dB	Range limits	
SlowMax	1/2, 1/4, 1/15, 1/30, off, 1/8		
Shutter	2/1, 1/1, 1/2, 1/4, 1/8, 1/15, 1/30, 1/60, 1/90, 1/100, 1/125, 1/180, 1/250, 1/300, 1/500, 1/725, 1/1000, 1/1500, 1/2000, 1/3000, 1/4000, 1/6000, 1/10000	Manual shutter speeds, based around 60fps	
Iris	0 ~ 100%	Manual, seems to use only 0~20%	
Gain	0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30, 32, 34, 36, 38, 40, 42dB	Manual gain control	Max 12dB ¹
Focus			
Item	Range	Description	
Far		Big buttons for focusing	
Near			
Mode	Auto, Manual, Infinity		
Area	Narrow, Norm, Wide, Area1~9	Auto controls	
Sensitivity	Normal, Low		
Speed	0, 1, 2, 3		
OnePush			
Zoom			
Item	Range	Description	
Wide		Big buttons	
Tele			
Digital	On, Off	Electronic zoom, not a good idea	
Speed	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10		
Picture			
Item	Range	Description	
WDR	On, Off	Wide Dynamic Range, not tested	
Flip	On, Off		
Mirror	On, Off		
Aperture	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15		4 ²

¹ Noise levels are poor above 12dB gain, even with Noise Reduction

² Edge enhancement appears to work only on green, giving noticeable green edges

Gamma	0.3, 0.45, 0.475, 0.5, 0.525, 0.575, <u>0.6</u> , 0.8, 1	0.5 ³
Black Level	-63 ~ <u>0</u> ~ +63	
SetupOn(VBS only)	On, <u>Off</u>	
Color Bar	On, <u>Off</u>	100% bars
Picture		
Item	Range	Description
Eclipse	<u>0</u> ~ 16	'Set the masking at high luminance level' not tested
Defog	<u>0</u> ~ 16	Not tested
Mode	AWB, Indoor, Outdoor, Manual, ATW	
AWB-Shift	Normal, R-Low, R-Mid, R-High, B-High, B-Mid, B-Low	
Cr	-20 ~ <u>0</u> ~ +20	
Cb	-20 ~ <u>0</u> ~ +20	
R	<u>0</u> ~ 511	
B	<u>0</u> ~ 511	
OnePush		Big button
Preset Shot		
Item	Range	Description
Save	On, <u>Off</u>	
Auto	On, <u>Off</u>	
Int	<u>0</u> ~ 1000	
Buttons 1~4		Select preset
	0 ~ 50 ~ 160	100msec multiples, transition times
All Preset Reset		Big button
External Sync		
Item	Range	Description
Enable	On, <u>Off</u>	
H	<u>0</u> ~ 2639	
V	<u>0</u> ~ 15	
Write		Big button
HD Format		
Item	Range	Description
Mode	1080p60, 1080i60, 1080p30, 1080p50, 1080i50, 1080p25, 720p60, 720p30, 720p50, 720p25, 1080p24	1080 ⁴
NTSC (59.94Hz)	On, <u>Off</u>	Discounted frame rates
ICR		
Item	Range	Description
ICR Auto	On, <u>Off</u>	
Delay	<u>0</u> ~ 255	
Out	<u>0</u> ~ 76	
In	<u>0</u> ~ 76	
Icr On	On, <u>Off</u>	Manual control
Screen (max. 10char)		
Item	Range	Description
Left-Up	On, <u>Off</u>	
Blink	On, <u>Off</u>	
	text	
Colour	<u>White</u> , Yellow, Violet, Red,	

³ Gamma 0.5 is a reasonable match to ITU.709

⁴ Resolution is poor, but very poor in 720p

	Cyan, Green, Blue		
Right-Up	On, <u>Off</u>		
Blink	On, <u>Off</u>		
	text		
Colour	<u>White</u> , Yellow, Violet, Red, Cyan, Green, Blue		
Left-Down	On, <u>Off</u>		
Blink	On, <u>Off</u>		
	text		
Colour	<u>White</u> , Yellow, Violet, Red, Cyan, Green, Blue		
Right-Down	On, <u>Off</u>		
Blink	On, <u>Off</u>		
	text		
Colour	<u>White</u> , Yellow, Violet, Red, Cyan, Green, Blue		
Menu			
Item	Range	Description	
Mode			
Zoom			
DZ Enable	On, <u>Off</u>	Digital zoom extension	
DZ Combine	On, <u>Off</u>		
DZ Expand	x1 ~ x12	Not available in 'combine' mode	
Focus			
Mode	<u>Auto</u> , Manual, Inf	Inf sets to infinity	
Auto Type	<u>Norm</u> , Intv, Zoom	Intv activates at intervals, Zoom when zoom stops	
Sensitivity	<u>Norm</u> , Low		
Intv Time	<u>5</u> , 10, 30sec		
Manual Type	<u>None</u> , Zoom	Zoom reverts to AF after a zoom operation	
AF-Det Area	Narrow, <u>Normal</u> , Wide, Area1~9	Area1~9 is top-left, top-mid, top-tight ... bottom-mid, bottom right	
Color			
AWB	<u>Auto</u> , Indoor, Outdoor, Manual, ATW	Auto is only 3000~5000K, ATW better than 2600~8000K	
AWB Shift	Norm, R-Low, R-Mid, R-Hi, B-Hi, B-Mid, B-Lo		
Manual RG	-10 ~ <u>0</u> ~ +10	VISCA control is much more fine, 0~511 Chroma gain	
Manual BG	-10 ~ <u>0</u> ~ +10		
CR Gain	-20 ~ <u>0</u> ~ +20		
CB Gain	-20 ~ <u>0</u> ~ +20		
Auto Exposure			
Mode	<u>Auto</u> , Manual, Shut-P, Iris-P, Manual2	Not sure about Manual/Manual2	
Compensation	-6 ~ <u>0</u> ~ +6dB	Offset for Auto	
Max Gain	0 ~ <u>42dB</u>	Limit gain in Auto	
Manual gain	<u>0</u> ~ 42dB		
Manual Speed	2/1 ~ 1/10000sec	Applies to Manual/Manual2 and Shut-P	
Manual Iris	Close ~ F1.6		
Response	<u>Normal</u> , Slow, Fast	AE speed	
AE-Det Area	Narrow, <u>Normal</u> , Wide, Area1~9	Area1~9 is top-left, top-mid, top-tight ... bottom-mid, bottom right	
Auto Slow	OFF, 1/25, 1/12, 1/6, 1/3, 1/1.5	Shutter limit when Auto gain is max	
Pre Gain	<u>0</u> , 6dB	Basic sensitivity	
Peak Comp	<u>0</u> ~ 16	The manual says it reduces halation	
Eclipse	<u>0</u> ~ 16	Not explained in the manual	
Auto ICR			
Mode	On, <u>Off</u>		

⁵ Iris diffraction worsens resolution significantly about F/6.3

IR Status	display		
Delay	<u>0</u> ~ 255	1/10 second steps	
D>N	<u>0</u> ~ 76	Too complicated to explain here, see the manual, section 4.2.7	
N>D	<u>0</u> ~ 76		
Focus Adj	On, <u>Off</u>		
HD Format			
Format	1080p60, 1080i60, 1080p30, 1080p50, 1080i50, 1080p25, 720p60, 720p30, 720p50, 720p25, 1080p24	All the 60/30/24 speeds change down by 1/1.001 for 'NTSC'	1080 ⁶
NTSC	Enable, <u>Disable</u>	Does nothing to the 50/25 speeds	
Gen Lock	<u>Off</u> , On	Analogue SD/HD input needed	
Offset-X	<u>0</u> ~ 2369	Timing shift	
Offset-Y	<u>0</u> ~ 15		
Picture			
Enhancer	<u>0</u> ~ 15	No details in the manual	4
Gamma	0.3, 0.45, 0.476, 0.5, 0.525, 0.575, <u>0.6</u> , 0.8, 1	No details in the manual	0.5
Mirror	<u>Off</u> , On	Horizontal reversal	
Up-Down Flip	<u>Off</u> , On	Vertical reversal	
Effect	<u>Off</u> , Neg, B&W	Automatically goes B&W in IR Cut	
Black Level	-63 ~ <u>0</u> ~ +63	127 steps	
Noise Filter	<u>Off</u> , On, Auto	No details in the manual	On
Alarm			
Mode	AF Type1, AF Type2, AE Type1, AE Type2, AEAF Type, Day Night	Too complex to explain here, see the manual section 4.2.10	
Start	<u>Off</u> , On	Enable the alarm	
Day Level	<u>0</u> ~ 255	Pixel levels (8-bit), not explained in the manual	
Night Level	<u>0</u> ~ <u>255</u>		
Privacy Mask			
Mask Select	<u>Mask A</u> ~ Mask H	Not tested	
Mask On/Off	On, <u>Off</u>		
Others			
WDR Mode	<u>Off</u> , On	'Wide Dynamic Range'	
Defog Level	<u>0</u> ~ 16		
Color Bar	<u>Off</u> , On		
Comm Menu 4.2.13	<u>Off</u> , On		
Comm. Speed	9600, 19200, 38400bps		
Cmd Type	None, VISCA, PELCO-D		
Firm version	display	Firmware	
Data Version	display	Set of Default settings	
TV Setup	<u>Off</u> , On	7.5% lift for NTSC	
Audio Mode	<u>Off</u> , L-Mono, LR-Mono		
Audio Level	0, -10, -20dB		
Memory			
Select	None, Mem1, Mem2, Mem3, Mem4	Settings memories	
Action	Recall, Save		

⁶ 720p is very poor

2. Measurements

All measurements were made on frames captured onto a CFast card in a Convergent Design nanoFlash recorder, at 50Mb/s MPEG Long GoP or 100Mb/s I-frame for noise-critical measurements. Live viewing was done on a 50" Panasonic 4k television (TX50DX750). Clips were ingested into Edius 8.20 and images for this document were extracted as BMP files.

2.1. Colour performance

A standard Colorchecker chart was exposed, using tungsten illumination. 'Indoor' preset white balance was used.

Fig.1 shows the performance with gain setting 0dB and gamma 0.5. The white balance was a little pink and skin tones not were not well reproduced, and the third row of colours appear a little desaturated.

There was no response to infra-red, with the IR cut filter in place. Without it, the pictures are monochrome, and the camera is about 2 stops more sensitive.

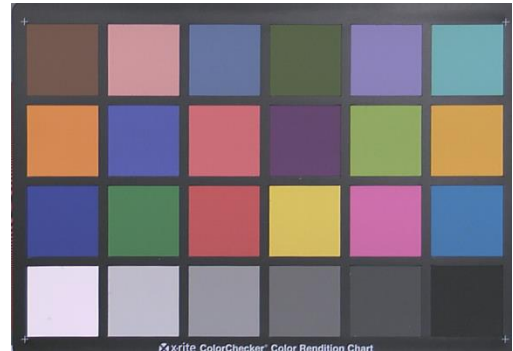


Figure 1 Colorchecker, gamma=0.5

2.2. Gamma curve and Dynamic Range

The Colorchecker chart was exposed several times with tungsten illumination, at 0dB gain and using the shutter to control exposure level. The gamma curve was extracted using the measured levels for the grey scale patches.

Fig. 2a shows the curve. The black points are measurements, the green line is a theoretical ITU.709 curve. During this analysis, it became clear that the luma signal reaches 109.1%, i.e. it is not clipped at all. The measurements are a reasonable match to ITU.709. The dynamic range is about 250:1, 8 stops.

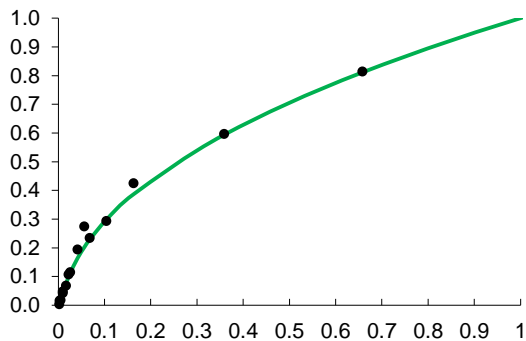
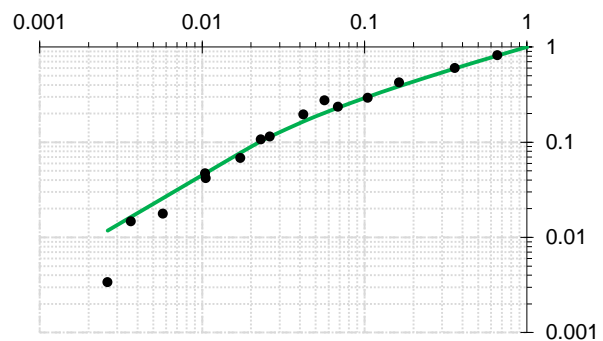


Figure 2 Gamma curve a: linear axes



b: logarithmic axes

Fig. 2b shows the same data replotted with logarithmic axes.

On a subsequent attempt to test the 'WDR' mode, the camera would not respond to serial data commands. No amount of reconnecting or powering up/down made any difference, so the attempt was abandoned.

2.3. Resolution and aliasing

Tests were made at 0dB gain and 14% iris value, at mid-zoom, with the usual zone-plate test chart. Fig.4 shows some barrel distortion at the extreme wide end of the lens, this becomes pincushion if the camera is zoomed in a little.

Fig.5 shows a luma quadrant, shot at extreme wide, with various edge-enhancement settings. Clearly, the image is very soft without any enhancement, but the default level of 8 is too high since it has



Figure 4 Extreme wide angle

increased the low-frequency contrast much more effectively than the actual resolution. Aliasing is almost completely absent, but the image is not sharp enough to qualify as an HD camera.

Fig. 6 shows the zone plate at close-up and telephoto, with the same edge setting (4). It is much sharper at the long end of the lens, and the reduced edge setting has enhanced the resolution a little without doing too much damage by enhancing aliasing, although the level of aliasing is rather worrying. Overall, resolution is poor for a camera claiming to be HD.

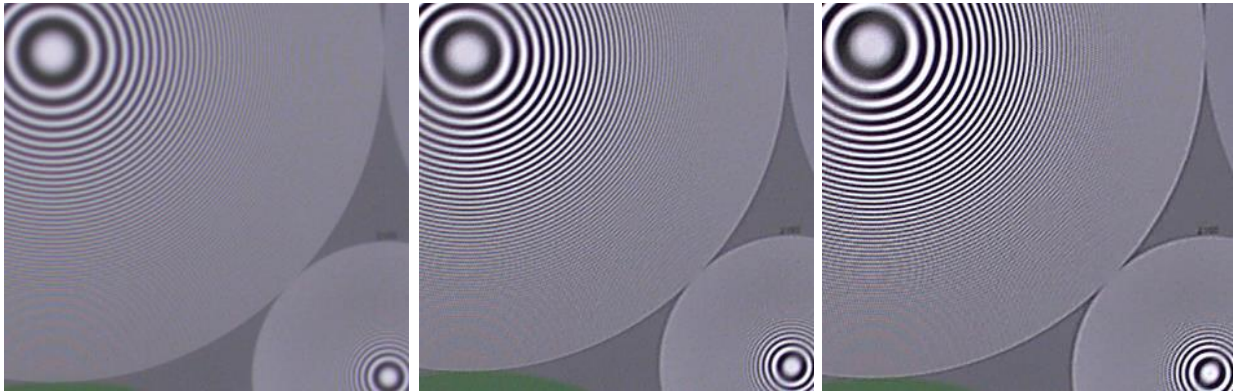


Figure 5 Zone plate, 1080p25
a: edge 0

b: edge 8

c: edge 15

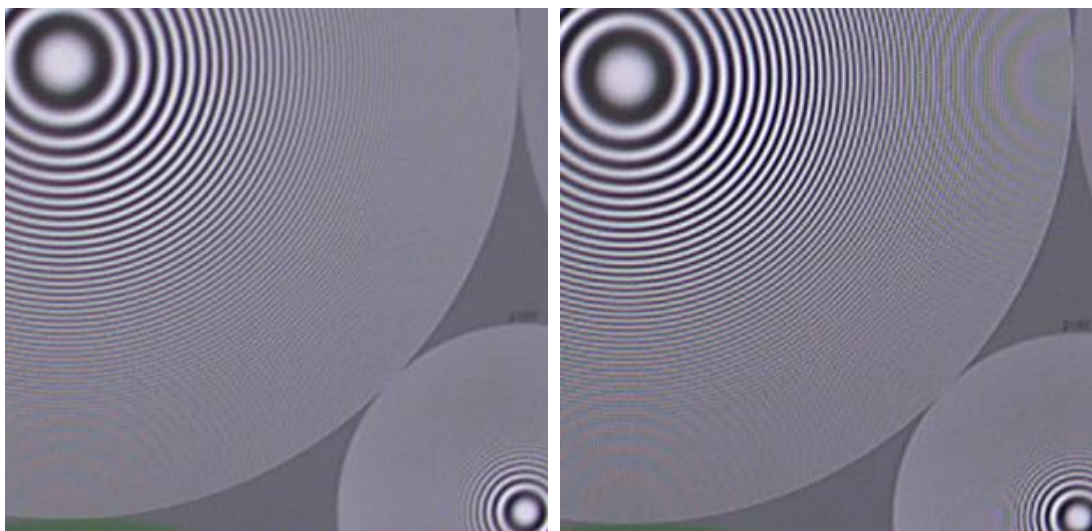


Figure 3 Zone plate, edge=4 a: wide

b: telephoto

2.4. Noise

2.4.1. Noise levels

The multiple exposures of the Colorchecker used in section 2.2 were also used to determine the noise profile, noise level versus signal level.

Fig.4 shows the profile, the black spots are measurements and their apparently wide distribution is normal for measurements made on small parts of the picture. The green trend line shows that noise levels change little with signal level, which is unusual. The wide spread of data results is a little worrying, and I cannot explain it.

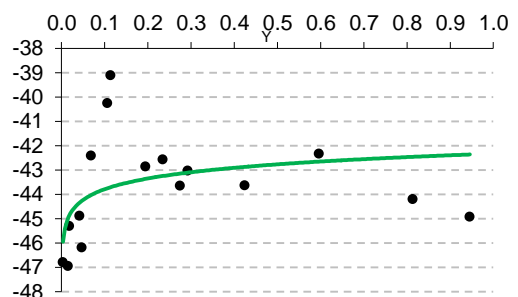


Figure 4 Noise profile

Conventionally, the noise level would be expected to rise near black since the differential gain applied by gamma correction affects the noise level, but here it drops dramatically. There are several possible reasons, but it is hardly worth exploring these since the user has no control over the noise profile. The noise level at 50% video is about -42dB which is the qualifying level for EBU R.118 HD Tier SP.

Next, the camera was exposed to a pair of Kodak Gray cards, showing 90% white and 18% grey sides together. Exposure was adjusted to achieve 50% luma level from the grey card over the full range of gain settings. Exposure was controlled using the shutter and iris.

Fig. 5 shows the result. The trend is normally a rise of 3dB in noise level per 6dB of signal gain, and this is neatly illustrated by the green trend line. Clearly, the noise level is unacceptable at most gain settings.

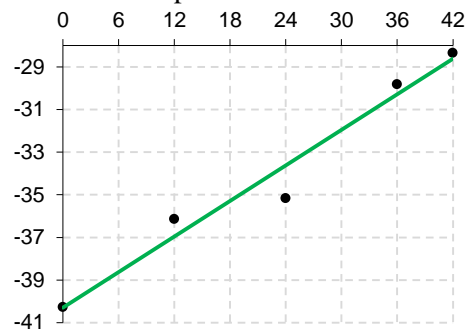


Figure 5 Noise vs Gain

2.4.2. Noise reduction

Exposures were made over the same range of gain settings, keeping the video level from the Kodak Gray (18%) at or very near 50%.

Fig. 6 shows the results: Noise Reduction off in black, On in red.

Very oddly, noise reduction of between 2 and 4dB is evident at low gain, where the noise levels are lowest, but at high gain and noise level, noise reduction is less than 1dB. Nevertheless, noise is lowered at low gain by a significant amount, meaning that gain settings of 6 or 12dB might be acceptable.

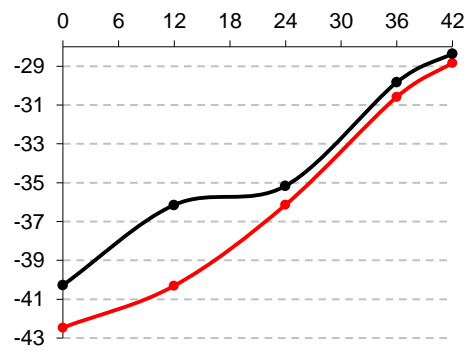


Figure 6 Noise reduction

However, noise reduction always comes at a price, usually a loss of resolution due to the action of the spatial filtering used in noise reduction.

Fig. 7 shows zone plate quadrants at 12, 18 and 24dB gain, with noise reduction on and off. Some resolution is lost at all settings, but not enough to be significant.

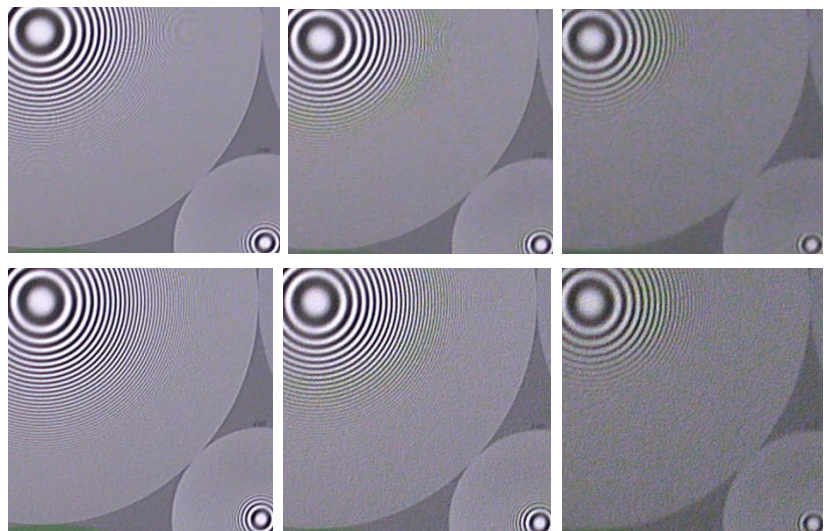


Figure 7 NR on, 12dB 18dB 24dB
NR off, 12dB 18dB 24dB

Note that these exposures were made with edge enhancement set at level 8, the default setting, and there is a clearly visible green 'halo' around the detail, suggesting that the edge enhancement works only on green and not on the luma channel. Not only that, but the loss of resolution at high gain is quite dramatic, even at 12dB the loss is significant.

2.5. Sensitivity

In a television camera, sensitivity is normally defined as the lens aperture required to produce 100% peak white from a white card with a reflectance of 90%, lit by 2000 lux. This usually assumes a standard setup condition of either no gamma-correction or a curve which follows the normal equation, i.e. without a knee, and with interlaced scanning using 1/50 exposure interval.

The most sensible approach is to use the Kodak Gray cards. The white side has a reflectance of 90%, the grey side has a reflectance of 18% which is 20% relative to the white side. However, there is a problem in

this camera: the iris control is not calibrated, it is marked as a number between 0 and 100% in the control surface, and as 17 steps in the menu, the two do not match.

It became clear from the tests that increasing the value beyond 20% made no difference to actual exposure, and so this is probably the fully-open setting, F/1.6 according to the specification. At this setting, and 0dB gain, 100% white level was achieved with 470lux. This corresponds to approximately F/3.2 at 2000 lux.

A conventional $\frac{2}{3}$ " camera has a sensitivity of about F/11. Taking the relative sizes of the photo-sites as a guide, we should expect a linear ratio of $5^2:2.75^2$ or 30% which is about 1.72 stops less, so we should expect this camera's sensitivity to be about F/6.3, so it is about 2 stops less sensitive than expected. It seems likely that the full dynamic range of the sensor is being use here, rather than about 2 stops less than the full range for a $\frac{2}{3}$ " camera, indicating that there is no headroom which could benefit from the use of a knee in the gamma curve.

2.6. Motion portrayal

The sensor is CMOS, which can be read either by scanning or by instantaneous transfer into a readout store. Scanning produces the so-called 'rolling shutter' effect. The simple test for this is to use a small desk fan, and to adjust the rotation speed such that strobing holds the blades almost stationary. Then, if the sensor is being scanned, the down-ward moving blade (right-hand) will be widened and the upward-moving blade narrowed. The effect is made much more visible by using a short shutter.

Fig. 8 shows still frames, shot at using 1/1000 shutter. The blades are badly distorted. With more normal shutter durations, the effect is rather less pronounced.



Figure 8 Rotating fan, 1/1000 shutter

2.7. Conclusion

The sensor qualifies the camera only for Tier SP. Its performance is not good, it is relatively insensitive and resolution could be much better. Motion portrayal is poor even for a camera with rolling shutter.

The control software is not particularly intuitive, and some of the controls do not appear to do what they should. Also, in the controls which have both a slider and left/right buttons, I found that the state of the control was not indicated correctly unless only the slider was used, pressing the left/right buttons changed the camera setting but the fact was not indicated in the control surface. This could be highly confusing to the uninitiated operator.

Noise levels satisfy the requirements for Tier SP of R.118 (i.e. better than -42dB), but only using noise reduction, and even then 12dB gain is only marginally acceptable. Resolution is generally poor, and gets significantly worse as the gain is increased. Dynamic range is only about 8 stops, and it was not possible to test the Wide-Dynamic-Range function. Infra-red response is zero when the IR filter is in use.

Overall, the camera qualifies for R.118 Tier SP, but only just.