

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

Alan Roberts, June 2016

### **SUPPLEMENT 22: Assessment of a CIS VCC-HD10ZM 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 CIS mini-camera, model VCC-HD10ZM, serial number T15041001. It has a single Bayer-patterned CMOS sensor of nominal  $\frac{1}{3}$ " dimensions (actually 5.346x3.336mm and 1944x1213 photo-sites). The photo-sites are spaced at 2.75 $\mu$ m, thus 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 (3G HDS DI), 1920x1080i at 60/59.94/50/30/29.97/25/24/23.97fps (1.5G HDS DI), 1280x720p at 60/59.94/50fps (1.5G HDS DI). HDS DI output is 10-bit.

The integral lens is 18:1 zoom, 4.7 to 84.6mm, F1.6 to F2.8 at the telephoto end.

Being a mini-camera, it has no controls or viewfinder. The only connectors are a BNC for HDS DI output, 3.5mm mini-jack for serial control (tip, 2-ring and sleeve), and a small locking Hirose 6-pin connector for power, sync and timecode inputs.

Control is by custom software via serial data using VISCA protocol, a Windows version was used for the tests. Some of the camera functions can be controlled via an on-screen menu, which can be navigated using a small joystick button on the back of the camera.

The camera body is 116x62x56mm overall and weighs about 280 grams. Power consumption is 6.5W at 10~15volts DC.

The camera performed quite well under test, although 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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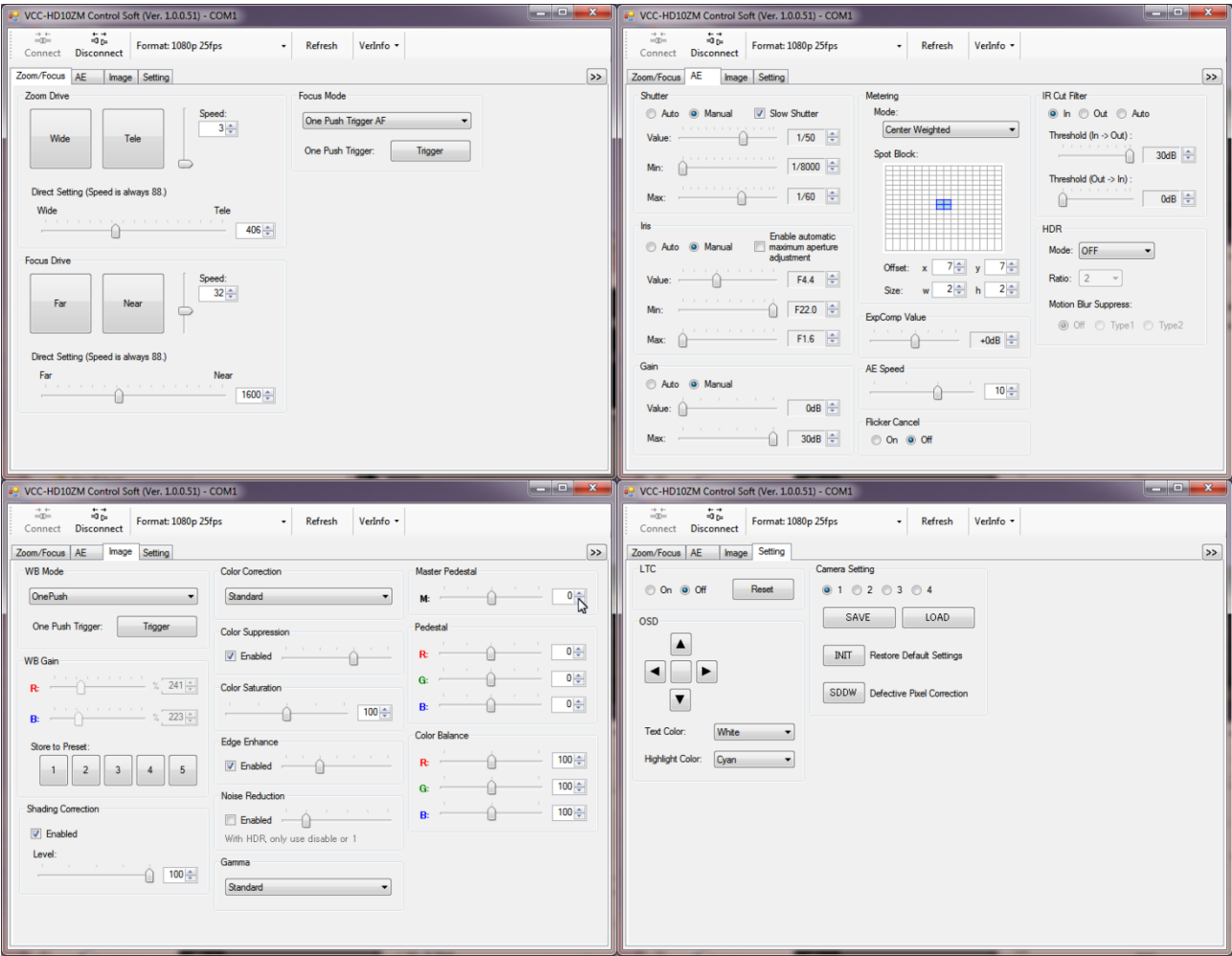
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Measurement results are given in section 3, after the menus. Measurements were made according to the procedures set out in EBU Tech.3335.

This listing of the menus and contents is complete, but this should not be used as an excuse for not reading the manuals. Items in the listing which affect image quality are highlit, and my recommended settings given. Default values, where known, are underlined>.

The software has four tabs which allow control of most functions :



But some significant controls are available only via the on-screen menu, which duplicate much of these tabs.

**1. Menu contents**

Across the top			
Item	Range	Description	Pref

Connect		Connect to the camera	
Disconnect		Disconnect the camera	
Set Video Format		1080p and I, 720p, at all the frame rates	1080 <sup>1</sup>
Refresh		Read the camera data	
Ver Info			
<b>Zoom/Focus tab</b>			
<b>Item</b>	<b>Range</b>	<b>Description</b>	
Zoom		Wide, Tele	
Buttons	0 ~ <u>1</u> ~ 1024	Slider and up/down buttons	
Speed		Slider and up/down buttons	
Wide/Tele			
Focus Drive		Far, Near	
Buttons	<u>0</u> ~ 3840	Slider and up/down buttons	
Speed	0 ~ <u>1</u> ~ 88	Slider and up/down buttons	
Far/Near	Auto, Manual, One Push AF		
Focus Mode			
One Push Trigger			
<b>AE tab</b>			
<b>Item</b>	<b>Range</b>	<b>Description</b>	
Shutter	<u>Auto</u> , Manual	Enables relevant items below	
Slow shutter	On, <u>Off</u>	Enables shutter speeds below the frame rate	
Value	1/8 ~ <u>1/fps</u> ~ 1/8000	Close intervals, equivalent to about 1/4 stops	
Min	1/8 ~ 1/fps ~ <u>1/8000</u>	Set the range for auto shutter	
Max	<u>1/fps</u> ~ 1/8000		
Iris	<u>Auto</u> , Manual	Enables relevant items below	
Enable auto max aperture adjustment	On, <u>Off</u>		
Value	<u>F/1.6</u> ~ F/22	1/4 stop steps	
Min	F/1.6 ~ <u>F/22</u>	Set the range for auto iris	F/6.3 <sup>2</sup>
Max	<u>F/1.6</u> ~ F/22		F/1.6
Gain	<u>Auto</u> , Manual	Enables relevant items below	
Value	0 ~ 30dB	1dB steps	
Max	0 ~ 30dB		20dB <sup>3</sup>
Metering	Average, <u>Center Weighted</u> , Spot, Backlight Compensation		
Spot Block		Graphic display of spot size/position	
Offset x	0 ~ <u>7</u> ~ 15		
Offset y	0 ~ <u>7</u> ~ 15		
Size w	1 ~ <u>2</u> ~ 16		
Size h	1 ~ <u>2</u> ~ 16		
ExpComp Value	-18 ~ <u>0</u> ~ +18dB	Offset for auto exposure	
AE Speed	0 ~ <u>10</u> ~ 15	Response speed	
Flicker Cancel	On, <u>Off</u>		
IR Cut Filter	<u>In</u> , Out, Auto		
Threshold (In>Out)	0 ~ <u>30dB</u>	Set when IR filter operates in Auto	
Threshold (Out>In)	<u>0</u> ~ 30dB		
HDR	<u>Off</u> , On (Manual), On (Auto1), On (Auto2)	Auto2 handles clipping better	
Ratio	<u>2</u> , 4, 8, 16, 32, 64	Appears to change exposure time	
Motion Blur Suppress	<u>Off</u> , Type1, Type2	HDR can generate false colours, this may help	
<b>Image tab</b>			
WB Mode	<u>Auto</u> , Auto (Outdoor), ATW, Daylight, Cloudy, Shade, Tungsten, FluorescentW, FluorescentN,	Enables relevant items below	

<sup>1</sup> 1080 performance is good, 1080p delivers a little more vertical resolution than 1080i, 720p is very poor

<sup>2</sup> Iris diffraction is dramatic above F/8

<sup>3</sup> Noise is bad above 20dB gain

	FluorescentD, OnePush, Manual, Preset1~5		
One PushTrigger		Press to balance	
WB Gain			
R	0 ~ <u>100</u> ~ 800	Percentage	
G	0 ~ <u>100</u> ~ 800		
Store to Preset		5 preset buttons	
Shading Correction	On, <u>Off</u>		
Level	0 ~ <u>100</u>		
Color Correction	<u>Standard</u> , Fluorescent Light, Tungsten Lamp		
Color Suppression	<u>On</u> , Off		
	0 ~ <u>5</u> ~ 7		
Color Saturation	0 ~ <u>100</u> ~ 200	Percentage	
Edge Enhance	<u>On</u> , Off		
	1 ~ <u>3</u> ~ 7		
Noise Reduction	On, <u>Off</u>		
	<u>1</u> ~ 6		
Gamma	Contrast-2, Contrast-1, <u>Standard</u> , Contrast+1, Contrast+2	Not explained in the manual, explored in the tests	Contrast-2 <sup>4</sup>
Master Pedestal	-100 ~ <u>0</u> ~ +100	Black levels	
Pedestal			
R	-100 ~ <u>0</u> ~ +100		
G	-100 ~ <u>0</u> ~ +100		
B	-100 ~ <u>0</u> ~ +100		
Colour Balance			
R	50 ~ 100 ~ 200	Percentage	
G	50 ~ 100 ~ 200		
B	50 ~ 100 ~ 200		
<b>Setting tab</b>			
<b>Item</b>	<b>Range</b>	<b>Description</b>	
LTC	On, <u>Off</u>	Timecode	
Reset			
Camera Setting	1, 2, 3, 4	Presets	
Save			
Load			
Init		Set factory settings	
SDDW		Defective pixel correction, best left well alone	
OSD		Centre button opens on-screen menu	
Text Color	Black, Blue, Green, Cyan, Red, Magenta, Yellow, <u>White</u>		
Highlight Color	Black, Blue, Green, <u>Cyan</u> , Red, Magenta, Yellow, White		
<b>OSD Menu</b>			
Output Format	1920x1080p ~ 1280x720p		1080 <sup>5</sup>
Gain/Shutter/Iris			
Gain Mode	Manual, <u>Auto</u>		
Gain Value	<u>0</u> ~ 30dB	1dB steps	
Gain Max Values	0 ~ <u>30dB</u>		20dB
Shutter Mode	Manual, <u>Auto</u>		
Shutter Value	1/4, 1/5, 1/6, 1/7, 1/8, 1/9, 1/11, 1/13, 1/15, 1/18, 1/21, 1/25, 1/30, 1/36, 1/42, 1/50, 1/60, 1/75, 1/90, 1/100, 1/105, 1/120, 1/125, 1/150, 1/180, 1/210, 1/250, 1/300, 1/350, 1/420, 1/500, 1/600, 1/700, 1/840, 1/1000, 1/1200, 1/1400, 1/1700, 1/2000, 1/2400, 1/2800, 1/3400, 1/4000, 1/4800, 1/5600, 1/6800, 1/8000	Manual speed	
Shutter Min Limit		Limits for auto	
Shutter Max Limit			
Iris Mode	Manual, <u>Auto</u>		
F number	F1.8, F1.8, F2, F2.2, F2.4, F2.6, F2.8, F3, F3.4, F3.6, F4, F4.4, F4.8, F5.2, F5.6, F6.1, F6.7, F7.3, F8, F8.7, F9.5, F10, F11, F12, F13, F15, F17, F19, F20, Close	Manual iris setting	

<sup>4</sup> Contrast-2 is a good match to ITU.709 gamma curve

<sup>5</sup> 720p is very poor, 1080i good for motion, 1080p slightly better for resolution

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Iris Open/Close		Open, Close		
Set Open/Close				Do it now
Iris Min Limit	F1.8, F1.8, F2, F2.2, F2.4, F2.6, F2.8, F3, F3.4, F3.6, F4, F4.4, F4.8, F5.2, F5.6, F6.1, F6.7, F7.3, F8, F8.7, F9.5, F10, F11, F12, F13, F15, F17, F19, F20			F/8 <sup>6</sup>
Iris Max Limit				Limits for Auto iris
Set Iris Limit				Do it now
AE Speed		0 ~ <u>10</u> ~ 15		
ExpCompValue		-18 ~ <u>0</u> ~ +18dB		
HDR Mode		<u>Off</u> , Manual, Auto1, Auto2		
HDR Ratio Value		<u>1:2</u> , 1:4, 1:8, 1:16, 1:32, 1:64		
Set HDR Ratio				Do it now
HDR MBC Mode		<u>Off</u> , On (Type1), On (Type2)		
Metering Mode	<u>Average</u> , Center Weighted, Spot, Backlight Comp			
Spot Block X		0 ~ <u>7</u> ~ 15		
Spot Block Y		0 ~ <u>7</u> ~ 15		
Spot Block W		1 ~ <u>2</u> ~ 16		
Spot Block H		1 ~ <u>2</u> ~ 16		
Set Spot Block				Do it now
Flicker Cancel		On, <u>Off</u>		
White Balance				
WB Mode	<u>Auto</u> , Outdoor, Daylight (Sun ight), Cloudy, Shade, Tungsten, Flw (Fluorescent White), Fln (Fluorescent noon white), Fld (Fluorescent day light), Auto(ATW), One push, Manual, Preset1~5			
WB Red Gain		0 ~ <u>100</u> ~ 800		
WB Blue Gain		0 ~ <u>100</u> ~ 800		
One Push Start				Do it now, press centre button
Set Preset Number		1 ~ 5		Save settings, press centre button
Image Control				
Red Balance		50 ~ <u>100</u> ~ 150		
Green Balance		50 ~ <u>100</u> ~ 150		
Blue Balance		50 ~ <u>100</u> ~ 150		
Master Pedestal		-100 ~ <u>0</u> ~ +100		
Red Pedestal		-100 ~ <u>0</u> ~ +100		
Green Pedestal		-100 ~ <u>0</u> ~ +100		
Blue Pedestal		-100 ~ <u>0</u> ~ +100		
Edge Level		0 ~ <u>2</u> ~ 7		
Contrast	Contrast-2, Contrast-1, <u>Standard</u> , Contrast+1, Contrast+2			Gamma curve
Shading Correction		<u>Off</u> , On		Presumably spherical modulation
Shading Level		0 ~ <u>100</u>		
Noise Reduction		0 ~ <u>1</u> ~ 6		
Color Saturation		0 ~ 100 ~ 200		Percentage
Color Correction		Standard, Fluorescent, Tungsten		
Color Suppression		0 ~ <u>5</u> ~ 7		
Lens Control				
Focus Mode		Auto, Manual, AF OnePush Trigger		
Set One Push Focus				Do it now
Focus Position		<u>0</u> ~ 3840		
Focus Speed		0 ~ <u>1</u> ~ 88		
IR Cut Filter Mode		<u>Out</u> , In, Auto		
IR Cut Out Threshold		0 ~ <u>30dB</u>		1 dB steps
IR Cut In Threshold		<u>0</u> ~ 30dB		
LTC				
LTC		<u>Off</u> , On		
Set LTC Reset				Press centre button to reset time code
OSD Color Change				
Default Set				Press centre button for white/cyan
User Setting				

<sup>6</sup> Iris diffraction is visible at F/6.3, a problem at F/8, nasty above this

Menu Colour	Black, Blue, Green, Cyan, Red, Magenta, Yellow, <u>White</u>		
Highlight Colour	Black, Blue, Green, <u>Cyan</u> , Red, Magenta, Yellow, White		
Set Color		Press centre button for selection	
INIT			
Init		Press centre button for factory reset	
Save/Load			
Set Save Data	0 ~ 3		
Really?	No, Yes		
Enter		Do it now	
Get Save Data	0 ~ 3	Press centre button to do it	

## 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 at 100Mb/s I-frame where noise performance was critical. The nanoFlash cannot record the 3GB/s formats, so tests were constrained to the 1.5GB/s formats. 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. The camera was set to Tungsten white balance.

Fig.1 shows the performance with gain setting 0dB. Colour performance showed no problems.

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

### 2.2. Gamma curve and Dynamic Range

The Colorchecker chart was exposed with tungsten illumination several times, at F/5.2 and using the shutter to vary the exposure level. The gamma curve was extracted using 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 is clipped at 100%. The measurements are a reasonable match to ITU.709, and there is no evidence that there is a knee in the curve. The dynamic range is between 800 and 900:1, nearly 10 stops.

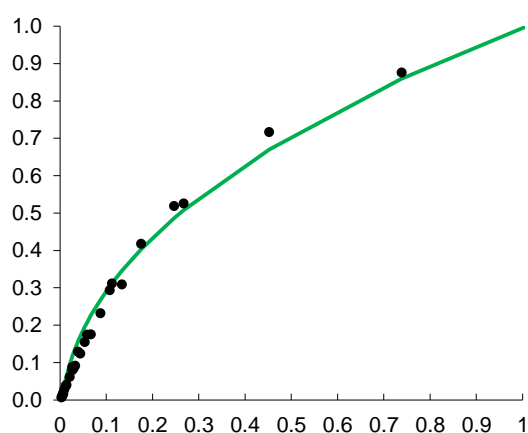
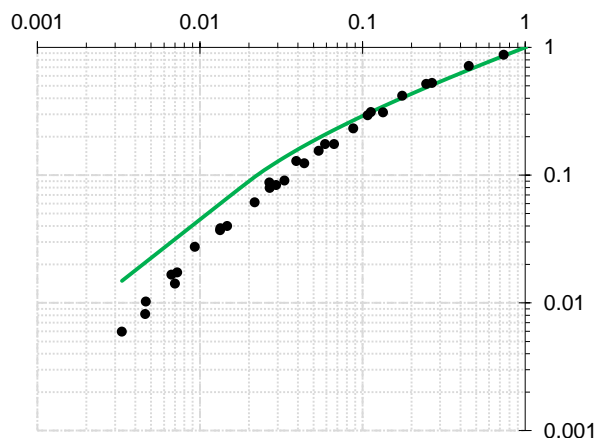


Figure 2 Gamma curve a: linear axes



b: logarithmic axes

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

### 2.3. Resolution and aliasing

Tests were made at F/4.4 with the usual zone-plate test chart. If the lens is used at the widest extreme focal length, there is a little barrel distortion, but this rapidly changes to pincushion as the lens is zoomed in. Neither effect is dramatic, and should not be a problem.

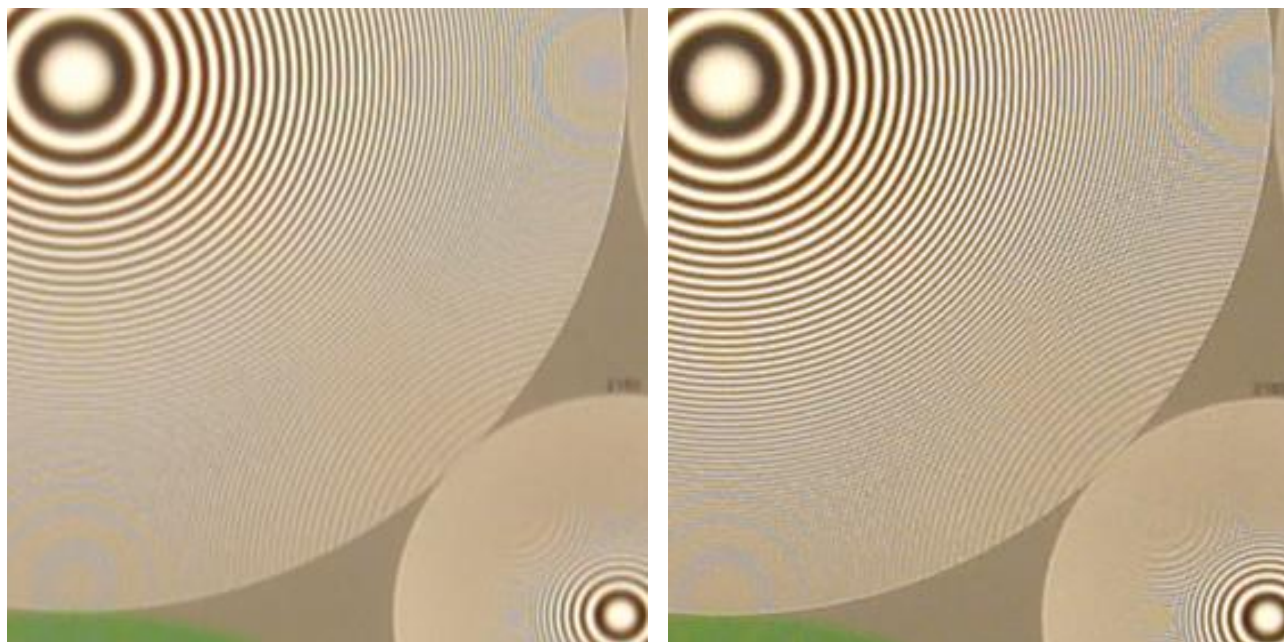
Fig. 3 shows the zone plate chart at the full wide end of the lens (also showing the on-screen menu) and at medium telephoto.



Figure 3 a: full wide b: medium telephoto

Fig. 4a shows a quadrant of the luma

pattern in interlace mode (1920x1080i/50), Fig. 4b in progressive mode (1920x1080p/25, i.e. psf or



**Figure 4 Zone plate a: interlaced**

**b: progressive**

progressive with segmented frames). Both results use the default Edge Enhance setting of 3. Diagonal aliasing is evident in both modes, as expected. There is little aliasing from detail outside the limits of HD, as seen in the smaller pattern which reaches 3840x2160.

The level of aliasing is normal for a single sensor with Bayer pattern, and the photo-site dimensions of the image format, 1920x1080. Horizontal and vertical coloured aliasing is normal because of the difference in resolution of the G channel from R/B. Resolution is good up to about 1550 horizontally, and 795 vertically in progressive mode, but vertical resolution extends only to about 585 in interlaced mode. This, slightly disappointingly low resolution, goes with the rather better-than-expected level of aliasing.

When the lens is stopped down beyond about F/6.3, resolution is reduced through iris diffraction, an inevitable result of the use of a small sensor. However, the level of aliasing also goes down, so F/8 is potentially useful in 1280x720p mode, but not in 1920x1080.

Resolution at 1280x720 is shown in Fig. 5. It is not good at all, the resolution is inadequate for the format and the down-scaling is too simple in that it does not reject the higher frequencies present in the source 1920x1080 image. 1280x720 should be avoided unless there is a good reason to use it.



**Figure 5 Zone plate, 1280x720**

### **2.3.1. .Aperture, Edge Enhance**

The effect of the aperture control was investigated at F/4.4 where the lens is sharpest. The Aperture control has a scale, 1 ~ 7. Results are shown in Fig.6.

Although the control is rather severe, the standard setting, 3, appears to be quite acceptable. Using higher levels increases the resolution a little, but also delivers significantly more aliasing, and so should be avoided.





Figure 6 Zone plate a: Edge 2

b: Edge 4

c: Edge 7

## 2.4. Noise

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.7 shows the profile, the black spots are measurements and their apparently wide distribution is normal for measurements made on small parts of the picture.

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 -43dB which better than is the qualifying level for EBU R.118 HD Tier SP (-42dB). However, since the noise level falls from this level towards black, the pictures look much less noisy than these figures imply. This alone cannot qualify the camera for such a high tier because of other limitations.

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 (and 100% from the white card) over the full range of gain settings. Exposure was controlled using the shutter and iris.

Fig. 8 shows the result. The trend is normally a rise of 3dB in noise level per 6dB of signal gain, the green trend line has a slope of 2.5dB/6dB which is close enough.

Using gain settings higher than about 20dB should be avoided if possible, although noise reduction can improve this.

### 2.4.1. Noise reduction

To test this facility, exposures were made at selected gain settings, keeping the video level from a Kodak Gray (18%) at or very near 50%. Exposures were made with noise reduction off, and then with it set to level 2 and to maximum level 7. Fig. 9 shows the results, plotted as noise level in dB versus gain (black is NR off, green is NR 2, red is NR 6). Noise reduction is more effective as the noise levels rise, which is encouraging. At the extreme gain setting (30dB), the improvement is 10.5dB which is unusually high.

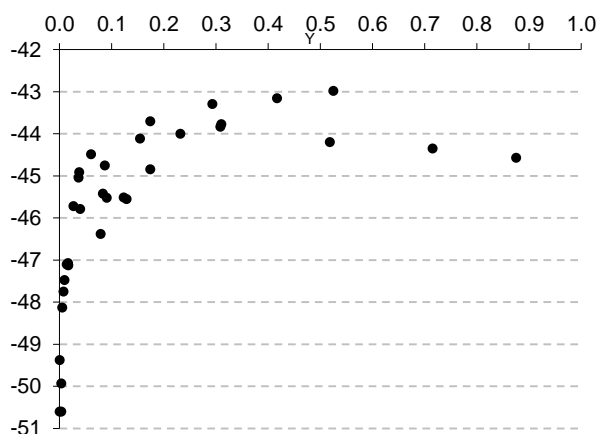


Figure 7 Noise profile, gain 0dB

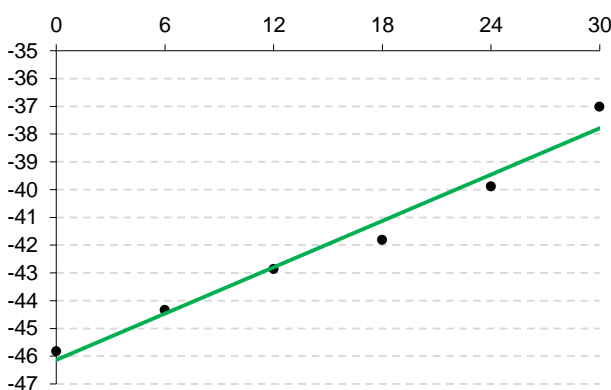
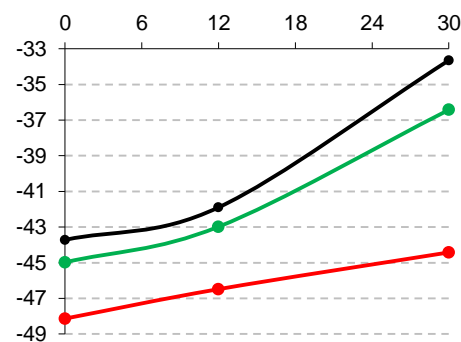


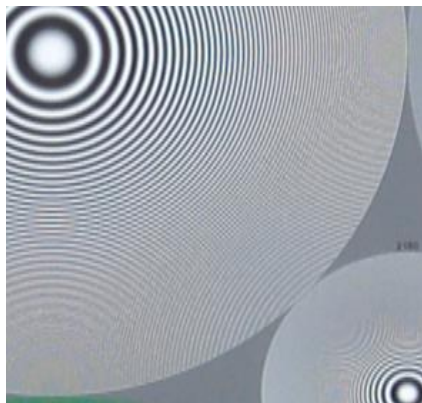
Figure 8 Noise vs gain

However, this comes at a price, reduction in resolution. Fig.10 shows a luma quadrant of the zone plate chart, shot at the same gain and noise reduction settings.

At 0dB gain, there is virtually no effect on resolution, even at maximum noise reduction. At 12dB gain, there is only a slight reduction in resolution together with a drop in levels of aliasing. At 30dB gain, there is even a slight improvement in resolution, as it is less polluted by noise. This is truly remarkable, there appears to be no reason for not using noise reduction, which can deliver dramatic lowering of noise levels. However, to be safe, a level of 2~4 ought to be acceptable at all other settings. With noise reduction so set, the gain could be set to 24dB with reasonable confidence.



**Figure 9 Noise reduction**



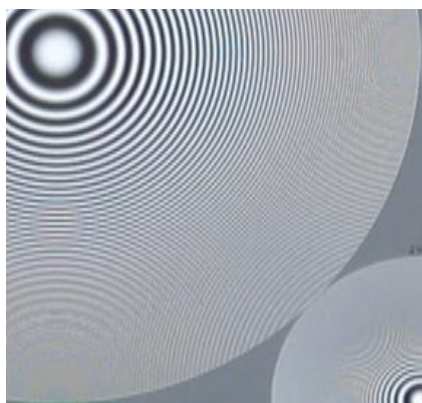
**Figure 10 Zone plate, NR off a: 0dB**



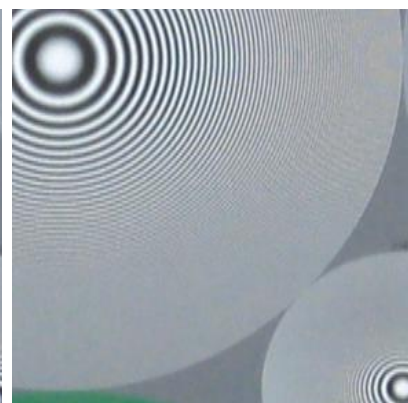
**b: 12dB**



**c: 30dB**



**Figure 10 Zone plate, NR 2 a: 0dB**



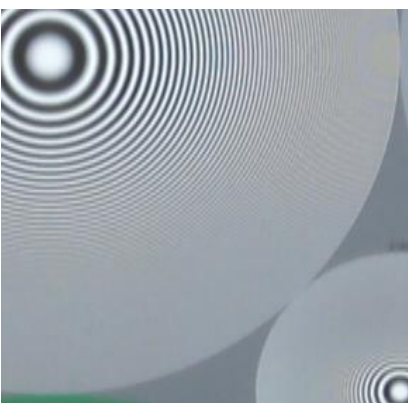
**b: 12dB**



**c: 30dB**



**Figure 10 Zone plate, NR 6 a: 0dB**



**b: 12dB**



**c: 30dB**

## 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 (1920x1080i/25, i.e. psf 25) 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. At a gain setting of 0dB, 100% exposure was achieved at F/4.2, compared with a conventional  $\frac{2}{3}$ " camera which normally measures at about F/11, about  $2\frac{2}{3}$  stops below. Taking the relative sizes of the photo-sites as a guide, we should expect a linear ratio of  $1\frac{3}{4}$  stops below that of the  $\frac{2}{3}$ " camera, so we should expect this camera's sensitivity to be about F/6.3, so it is about 1 stop less sensitive than expected. It seems likely that the full dynamic range of the sensor is being used 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. 11 shows a series of still frames using 1/1000 shutter, recorded in 1920x1080p/25 and 1920x1080i/25, with the final shot (i) recorded at 1080i with 1/00 shutter. At 1080p, the effect is dramatic while at 1080i it is merely poor. Even when the shutter duration is lengthened to 1/100 the effect is plain to see. Clearly this camera is not well suited to applications with rapid motion. 1920x1080p/50 should have the same performance as 1920x1080i/25.

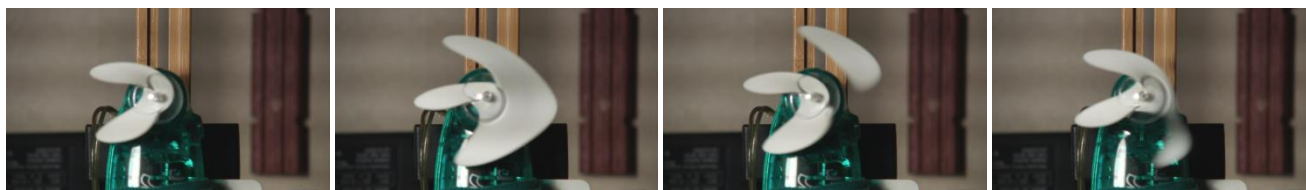


Figure 11 Motion distortion, 1/1000 shutter a,b,c,d: 1080p/25



Figure 11 Motion distortion, e,f,g: 1/1000 shutter 1080i/25

i: 1/100 shutter 1080i/25

## 2.7. Conclusion

The sensor qualifies the camera only for Tier SP. Its performance is quite good for its size, resolution and aliasing are reasonably well balanced. Noise performance is quite good, and the noise reduction particularly successful. Motion portrayal is poor even for a camera with rolling shutter.

Noise levels satisfy the requirements for Tier SP of R.118 (i.e. better than -42dB), through intelligent image processing. Dynamic range is as expected, about 9.5~10 stops. Infra-red response is zero when the IR filter is in use.

The control software is intuitive, and the important control buttons (focus and zoom) are quite big, making it easy to operate.