

## Colorimetric and Resolution requirements of cameras

Alan Roberts

### **ADDENDUM 66 rev.2 : tests and settings on a Panasonic AG-AF101**

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

Tests were made on to separate production models of the Panasonic AF101. Neither camera had a serial number at the time of testing. The camera has a single large CMOS sensor, presumably with Bayer-pattern, and a new lens mount designed to accept a new range of ‘micro 4/3’ lenses, or other large format lenses via mechanical adaptors. It records MPEG4-compressed video (AVC H.264).

The camera is clearly intended as a competitor in the range of large-format digital SLR cameras which record video, but has all the normal facilities of a video camera (attached viewfinder and side lcd display, many controls via external buttons rather than entirely via menus). Although the sensor is large by video standards, it is not large by SLR or film standards. Also, it seems that the sensor was not specifically designed for this camera, since some compromises have been made (see the measurements section for details).

Recording is onto SD/SDHC/SDXC cards, at 1920x1080 (interlaced or progressive psf) or 1280x720, at an impressive number of frame rates from 59.94 to 23.98Hz. However, recording data rates are rather low for broadcast use, 21, 17 or 6Mb/s. The camera will operate and record off-speed, in 1080 mode, at spot speeds between 12 and 50Hz or 60Hz depending on the system speed setting. It will also record from 3 seconds before pressing the Start button or record single frames at set intervals.

Signal outputs are available: video via BNC for HDSDI and SDDSI, HDMI, and analogue composite SD; audio input via XLRs. The analogue video socket doubles for setting timecodes when multiple cameras are used.

It is physically small (163x195x290mm) and light (1.3kg) for a broadcast camera, but there is no need for extra hardware in order to make it a usable camera, unlike video-shooting DSLRs. Power consumption is about 12.5 watts from a 7.2v volt battery, which identifies the design as being more aimed at consumer and semi-professional than at the broadcaster who would normally expect to use a conventional 12 volt battery pack. However, the top and side handles are removable, which makes it possible to customise the camera in unusual ways.

There are neutral filters for exposure control, and on-screen video level monitoring is good, there are options for waveform-monitoring on the LCD panel.

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Many of the menu items have little or no effect on image quality. Those that have significant effect are highlighted. The full set of menu items is given for completeness. In boxes with a range of numeric settings, e.g. -99~+99, the values indicate the range, and zero means no alteration to factory setting, not zero effect, and no scales are given in the manuals. For each item, the factory setting is underlined. "Pref" (preferred) settings are in the last column, where appropriate, for normal video shooting and for film-look shooting. Where no preferred value is given, either the factory setting is best, or the setting does not have great effect on image quality. Menus are nested: items in bold-face in the listing are headings leading to a further nested menu.

Camera settings which affect picture quality directly, such as gamma, detail and matrix are held in scene files (Custom Files). There is no direct way to access these from the camera, they are accessed using the Menu button on the camera handle. Control is simple, with a single joystick/button.

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.

Measurement results are given in section 2, after the menus.

## 1 Menus and settings

# SCENE FILE

|                |   |   | Main camera settings   |               |
|----------------|---|---|--|---------------|
| Item           | Range   | description   | Pref   |               |
|                |   |   | Video  | Film          |
| Scene select   | F1, F2, F3, F4, F5, <u>F6</u>                                     | 6 scene files   |  |               |
| Operation type | <u>Film cam</u> , Video cam                                       | <sup>1</sup>  |  |               |
| Rec format     | 59.94   | PH 1080/60i, PH 1080/30psf, <u>PH 1080/24p</u> , PH 720/60p, PH 720/30p, PH 720/24p, HA 1080/60i, HE 1080/60i |  |               |
|                | 50  | PH 1080/50i, PH 1080/25psf, PH 720/50p, PH 720/25p, HA 1080/50i, PH 1080/50i                                  | PH 1080/50i  | PH 1080/25psf |
| VFR mode       | On, <u>Off</u>  | Only for Film Cam and 1080/24p, 25p, 30p  |  |               |
| Frame rate     | 59.94   | 12, 15, 18, 20, 21, 22, <u>24</u> , 25, 26, 27, 28, 30, 32, 34, 36, 40, 44, 48, 54, 60                        | Only for Film Cam  |               |
|                | 50  | 12, 15, 18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 30, 32, 34, 37, 42, 45, 48, 50                                |  |               |
| Synchroscan    | 59.94   | 1/24.0~1/48~1/250/6   | Slowest changes with frame rate to 1/frame rate <sup>3</sup> |               |
|                | 50  | 1/25.0~1/48.0~1/250./0  |  |               |
| Detail level   | -7~ <u>0</u> ~+7  |   | 0 <sup>4</sup>   |               |
| V detail level | -7~ <u>0</u> ~+7  |   | -2   |               |
| Detail coring  | -7~ <u>0</u> ~+7  |   | 0 <sup>5</sup>   |               |
| Chroma level   | -7~ <u>0</u> ~+7  |   | 0  |               |
| Chroma phase   | -7~ <u>0</u> ~+7  |   | 0  |               |
| Color temp Ach | -7~ <u>0</u> ~+7  | Fine tweaks to colour balance in switch settings  |  |               |
| Color temp Bch | -7~ <u>0</u> ~+7  |   |  |               |
| Master ped     | -15~ <u>0</u> ~+15  | Black level   |  |               |
| A.iris level   | -6~ <u>0</u> ~+6  | Set auto iris level   |  |               |
| DRS            | <u>Off</u> , 1, 2, 3  | Video knee, compress peaks  | <sup>6</sup>   | Off           |
| Gamma          | HD norm, SD norm, High, B.press, <u>Cine-like D</u> , Cine-like V | HD=ITU709, SD=DVX100, Cine V for high contrast  | HD norm  | Cine-like D   |
| Knee           | <u>Auto</u> , Low, Mid, High                                      | Not relevant for Film Cam   | Mid <sup>7</sup>   |               |
| Matrix         | Norm1, Norm2, Fluo, <u>Cine-like</u>                              |   | Norm1  | Cine-like     |
| Skin dtl mode  | On, <u>Off</u>  | No more controls  |  |               |
| B/W mode       | On, <u>Off</u>  | Turns off all colour <sup>8</sup>   |  |               |
| Card read      | Slot1, Slot2, <u>No</u>   | Read 6 scene files from SD card <sup>9</sup>  |  |               |
| Card write     | Slot1, Slot2, <u>No</u>   | Write 6 scene files to SD card  |  |               |
| Load/Save/Init | Load, Save, Initialize, <u>No</u>                                 | Load/Save scene files, or reset to factory settings   |  |               |
| Name edit      | Yes, <u>No</u>  | Enter/edit scene file name  |  |               |

<sup>1</sup> Film Cam mode enables variable frame rate recording but disables slow shutter; gain is shown as ISO speed and synchroscan as a shutter angle. Video Cam mode enables slow shutter but disables variable rate recording, gain is shown in dB and synchroscan as inverse time (1/sec).

<sup>2</sup> 24P recording is genuine progressive, whole frames, psf is progressive carried via interlace, as usual.

<sup>3</sup> Synchroscan shutter shows as '10.0d...172.8d...180.0d...360.0d', degrees in steps of 0.5, when in Film Cam mode.

<sup>4</sup> Negative values of detail level may well be subtracting detail, which can help in lowering the level of spatial aliasing.

<sup>5</sup> Since the camera noise level is quite low, negative values might help a little.

<sup>6</sup> Setting DRS can help with contrast range capture, not needed for Cine curves, but in Video Cam mode could be useful. But DRS varies with content, unlike Knee.

<sup>7</sup> Knee curves not controllable apart from point setting, Low=8%, Mid=90%, High=100%.

<sup>8</sup> B/W mode is handy for checking the accuracy of white balance, since balancing works even in B/W mode, turn it on/off to check what parts of the picture are actually balanced to white.

<sup>9</sup> Each SD card can hold all 6 scene files as a block.

## SW MODE

| Item          | Range  | description  | Pref  |      |
|---------------|--|--|-------|------|
|               |  |  | Video | Film |
| Function knob | Inh, Focus, Iris, Yget, <u>Focus/Iris</u> , Focus/Yget   | Set what the Area operation of the Function Knob does  |       |      |
| Low gain      | Film   | ISO200, ISO250, ISO320, <u>ISO400</u> , ISO500, ISO640, ISO800, ISO1000, ISO1250, ISO1600, ISO2000, ISO2500, ISO3200 |       |      |
|               | Video  | -6, -3, <u>0</u> , 3, 6, 9, 12, 15, 18dB   |       |      |
| Mid gain      | Film   | ISO200, ISO250, ISO320, ISO400, ISO500, ISO640, <u>ISO800</u> , ISO1000, ISO1250, ISO1600, ISO2000, ISO2500, ISO3200 |       |      |
|               | Video  | -6, -3, 0, 3, <u>6</u> , 9, 12, 15, 18dB   |       |      |
| High gain     | Film   | ISO200, ISO250, ISO320, ISO400, ISO500, ISO640, ISO800, ISO1000, ISO1250, <u>ISO1600</u> , ISO2000, ISO2500, ISO3200 |       |      |
|               | Video  | -6, -3, 0, 3, 6, 9, <u>12</u> , 15, 18dB   |       |      |
| ATW           | Ach, Bch, Prst, <u>Off</u>   | Assign auto-tracking-white to the balance switch   |       |      |
| Iris dial     | <u>Down open</u> , Up open   | Pretty obvious   |       |      |
| User1 SW      | Inh, Rec check, Face detect, FA, Capture, ATW, ATW lock, Shot mark, Index, Last clip, Backlight, Spotlight, Blackfade, Whitefade | Factory=FA, focus assist   |       |      |
| User2 SW      |  | Factory=ATW lock   |       |      |
| User3 SW      |  | Factory=Rec check  |       |      |
| WFM           | Wave, Vector, <u>Wave/Vector</u>   |  |       |      |
| S/S SW inh    | 1, 2, <u>No</u>  | Disable right (1) or left (2) start/stop switch  |       |      |
| Face framing  | <u>Off</u> , Primary, All  | Frames detected faces  |       |      |

## RECORDING SETUP

| Item          | Range                                       | description                         | Pref  |      |
|---------------|---|-------------------------------------|-------|------|
|               |   |                                     | Video | Film |
| Prerec mode   | On, <u>Off</u>                              | Records from 3 seconds before start |       |      |
| Interval rec  | <u>Off</u> , 1sec, 10sec, 30sec, 1min, 2min |                                     |       |      |
| Relay rec     | On, <u>Off</u>                              | Smooth switching between SD cards   |       |      |
| PH audio mode | LPCM, <u>AC3</u>                            | LPCM is uncompressed audio          |       |      |
| Mic ALC       | <u>On</u> , Off                             | Auto mic gain <sup>13</sup>         |       |      |
| Mic gain1     | <u>-50</u> , -60dB                          |                                     |       |      |
| Mic gain2     | <u>-50</u> , -60dB                          |                                     |       |      |

## TC/UB SETUP

| Item    | Range          | description                                | Pref  |      |
|---------|----------------|--|-------|------|
|         |                |  | Video | Film |
| TC mode | DF, <u>NDF</u> | Drop-frame, for 59.94 system <sup>14</sup> |       |      |

<sup>10</sup> Note that the ISO settings are effectively in 2dB steps while gain settings are in 3dB steps.

<sup>11</sup> Monitoring is good but obscures much of the display. 'Wave/Vector' cycles through Off-Wave-Vector-Off.

<sup>12</sup> Interval rec records 1 frame each interval, this works only in PH mode, and sets automatically to 1080/24p or /25p depending on the system frequency.

<sup>13</sup> The mic gain controls override this setting.

|             |                          |                                     |               |
|-------------|--------------------------|-------------------------------------|---------------|
| TCG         | Free run, <u>Rec run</u> |                                     |               |
| TC preset   | Yes, <u>No</u>           | Set initial time code <sup>15</sup> |               |
| UB preset   | Yes, <u>No</u>           | Set user bits                       |               |
| Ext TC link | Master, Slave, <u>No</u> |                                     | <sup>16</sup> |

## AV IN/OUT SETUP

| Item               | Range                                 | description                                | Pref  |      |
|--------------------|---------------------------------------|--|-------|------|
|                    |                                       |  | Video | Film |
| SDI & HDMI out sel | <u>1080i/720p</u> , Downconv          | Output camera signals or downconversion    |       |      |
| SDI out            | On, <u>Off</u>                        |  |       |      |
| SDI 24psf          | On, <u>Off</u>                        | Not relevant for 50Hz system <sup>17</sup> |       |      |
| SDI EDH            | On, <u>Off</u>                        |  |       |      |
| Downcon mode       | Side crop, letter box, <u>Squeeze</u> |  |       |      |
| HP mode            | Live, <u>Recording</u>                | <sup>18</sup>                              |       |      |
| Test tone          | <u>On</u> , Off                       | Tone with colour bars                      |       |      |
| Video setup        | <u>0</u> , 7.5%A                      | Analogue output only, and 59.94 system     |       |      |
| Audio out          | <u>Ch1/Ch2</u> , Ch1, Ch2             | What comes out of AV out                   |       |      |

## DISPLAY SETUP

| Item           | Range   | description                                 | Pref  |      |
|----------------|---|---|-------|------|
|                |   |   | Video | Film |
| Zebra detect 1 | 50, 55, 60, 65, 70, 75, <u>80</u> , 85, 90, 95, 100, 105% | Leans right                                 |       |      |
| Zebra detect 2 | 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, <u>100</u> , 105% | Leans left                                  |       |      |
| Y get marker   | <u>On</u> , Off   | On shows Y value with Zebra <sup>19</sup>   |       |      |
| Safety zone    | <u>90%</u> , 4:3, 14:9, 1.85:1, 2:1, 2.35:1, Grid, Off    | Grid adds 9 grid lines                      |       |      |
| Centre marker  | <u>On</u> , Off   |   |       |      |
| Focus bar      | <u>On</u> , Off   |   |       |      |
| Rec counter    | Total, <u>Clip</u>  |   |       |      |
| Video out OSD  | On, <u>Off</u>  | Add v/f stuff to analogue out               |       |      |
| Iris meter     | <u>On</u> , Off   | Bar graph of exposure 'error' <sup>20</sup> |       |      |
| Date/Time      | <u>Off</u> , Time, Date, Time & Date                      | Adds to analogue out                        |       |      |
| Date format    | <u>Y-M-D</u> , M-D-Y, D-M-Y                               |   |       |      |
| Level meter    | <u>On</u> , Off   | Audio meter                                 |       |      |
| Zoom & Focus   | Off, Number, <u>mm/m</u> , mm/feet                        | Accuracy not guaranteed <sup>21</sup>       |       |      |
| Card & Battery | <u>On</u> , Off   |   |       |      |
| Other display  | Off, <u>Partial</u> , All                                 |   |       |      |
| LCD backlight  | +1, <u>0</u> , -1, -2, -3                                 |   |       |      |

<sup>14</sup> 24p automatically uses NDF, no option.

<sup>15</sup> Time code must be set to 0 or a multiple of 4 when 24p is used, or it all goes wrong.

<sup>16</sup> Join two cameras together via the analogue video output to synchronise timecodes, one camera must be Master, the other Slave.

<sup>17</sup> 24psf is only for 1080/24p mode, and not even then when shooting off-speed.

<sup>18</sup> The recording compressor imposes a delay, so switching to Live headphones can be better.

<sup>19</sup> Luma signal metering, very useful.

<sup>20</sup> Adds a bar graph. Shows whether exposure is higher or lower than the camera would give in Auto exposure.

<sup>21</sup> Focus metering works only with lenses which link into the camera electronics, and is not guaranteed to be accurate anyway.

|            |                       |  |  |
|------------|-----------------------|--|--|
| LCD set    |                       | Brightness, Color, Contrast                |  |
| EVF set    |                       | Brightness, Color, Contrast                |  |
| Self shoot | Normal, <u>Mirror</u> | Horizontal mirroring on LCD                |  |
| EVF mode   | <u>Auto</u> , On      | Auto disables the v/f when the LCD is open |  |
| EVF color  | <u>On</u> , Off       | Off makes the v/f mono                     |  |

## CARD FUNCTIONS

| Item          | Range                   | description         | Pref  |      |
|---------------|-------------------------|---------------------|-------|------|
|               |                         |                     | Video | Film |
| Card format   | Slot1, Slot2, <u>No</u> | Format SD card      |       |      |
| Card status   | Slot1, Slot2, <u>No</u> | Display card status |       |      |
| Clip property | Yes, <u>No</u>          | Show properties     |       |      |

## USER FILE

| Item           | Range                   | description                 | Pref  |      |
|----------------|-------------------------|-----------------------------|-------|------|
|                |                         |                             | Video | Film |
| Card read      | Slot1, Slot2, <u>No</u> | Read user files from card 1 |       |      |
| Card write     | Slot1, Slot2, <u>No</u> |                             |       |      |
| Load/Save/Init | Yes, <u>No</u>          |                             |       |      |

## META DATA

| Item             | Range                   | description                 | Pref  |      |
|------------------|-------------------------|-----------------------------|-------|------|
|                  |                         |                             | Video | Film |
| Card read        | Slot1, Slot2, <u>No</u> | Load metadata from card     |       |      |
| Record           | On, <u>Off</u>          | Simultaneous record to card |       |      |
| User clip name   | <u>Type1</u> , Type2    |                             |       |      |
| Meta data prop   | Yes, <u>No</u>          | Show metadata               |       |      |
| Clip counter set | Yes, <u>No</u>          | Reset COUNT to 1            |       |      |
| Meta int set     | Yes, <u>No</u>          | Reset all metadata          |       |      |

## OTHER FUNCTIONS

| Item        | Range                          | description                       | Pref  |      |
|-------------|--------------------------------|-----------------------------------|-------|------|
|             |                                |                                   | Video | Film |
| Lens check  | On, <u>Off</u>                 | Test comms with the lens          |       |      |
| IR remote   | On, <u>Off</u>                 | Remote control                    |       |      |
| Tally lamp  | Front, Rear, <u>Both</u> , Off |                                   |       |      |
| Clock set   |                                | Set the time/date                 |       |      |
| Time zone   | -12.00~0.00~+13.00             | Half hour steps                   |       |      |
| Power save  | On, <u>Off</u>                 | Turn off after 5 mins inactive    |       |      |
| Language    | English, Francais, Español     | Menu language                     |       |      |
| System freq | 59.94, 50Hz                    | <sup>22</sup>                     | 50    |      |
| System info |                                | Shows camera version info         |       |      |
| Lens info   |                                | Show lens info <sup>23</sup>      |       |      |
| Menu init   |                                | Set factory default <sup>24</sup> |       |      |

<sup>22</sup> Very important setting, 50 for PAL-land shooting, 59.94 for NSTC-land.

<sup>23</sup> Only for 'Four Thirds' and 'Micro Four Thirds' lenses which talk to the camera.

<sup>24</sup> Except Time Zone setting.

|                |  |  |  |
|----------------|--|--|--|
| Operation time |  | Show power-on time (5 digit)           |  |
| Update         |  | Update the software <sup>25</sup>      |  |
| Lens update    |  | Update the lens firmware <sup>26</sup> |  |

## PLAY SETUP

| <i>Item</i> |       | <i>Range</i>   | <i>description</i>                         | <i>Pref</i> |      |
|-------------|-------|--|--|-------------|------|
|             |       |  |  | Video       | Film |
| PB format   | 59.94 | 1080/60i (30psf), 1080/24p,<br>720/60p(30p), 720/24p |  |             |      |
|             | 50    | 1080/50i(25psf), 720/50p                             |  |             |      |
| Repeat play |       | On, <u>Off</u>                                       | Repeat clips                               |             |      |
| Resume play |       | On, <u>Off</u>                                       | When On, plays from last<br>played clip    |             |      |
| Skip mode   |       | <u>Clip</u> , Clip & Index                           | Set start position for play<br>after pause |             |      |

## THUMBNAIL

| <i>Item</i>    |  | <i>Range</i>                            | <i>description</i> | <i>Pref</i> |      |
|----------------|--|---|--------------------|-------------|------|
|                |  |   |                    | Video       | Film |
| Thumbnail mode |  | <u>All</u> , Same format, Marker, Index | Set display method |             |      |
| Indicator      |  | <u>On</u> , Off                         |                    |             |      |
| Data display   |  | <u>TC</u> , UB, Time, Date, Date & Time |                    |             |      |
| Date format    |  | <u>Y-M-D</u> , M-D-Y, D-M-Y             |                    |             |      |

## OPERATION

| <i>Item</i>  |  | <i>Range</i>                 | <i>description</i>         | <i>Pref</i> |      |
|--------------|--|------------------------------|----------------------------|-------------|------|
|              |  |                              |                            | Video       | Film |
| Delete       |  | All clips, Select, <u>No</u> | Delete clips not protected |             |      |
| Index        |  | Yes, <u>No</u>               | Add/delete index mark      |             |      |
| Clip protect |  | Yes, <u>No</u>               |                            |             |      |
| Copy         |  |                              | Copy clips, see the manual |             |      |

<sup>25</sup> Go to <http://pro-av.panasonic.net> for details of how to do this

<sup>26</sup> Go to the lens manufacturer's site for details of how to do this.

## 2 Measurement results

All measurements were made by capturing images via HDSDI, then importing the captured files into specialist software for decoding as bitmap files for analysis in specialist software. A RED lens was used, 18-50mm zoom with maximum aperture of F/2.8, mounted on a PL adaptor. There was a degree of looseness to the adaptor, sufficient to change focus settings during the test.

### 2.1 Colour performance and IR

Assessments were made visually, using Macbeth charts as usual. Performance was judged to be very good. Given that there is little control over colour performance apart from fixed transfer characteristics (gamma) and matrices, this is fortunate, but encouraging.

The camera does respond a little to infra-red illumination, as was proved by pointing at consumer-electronics remote control device into the lens, but at quite low level. But, only when the gain was set abnormally high (18dB, 3200ISO) was it clearly visible, and at such levels it will have no visible effect on colour performance.

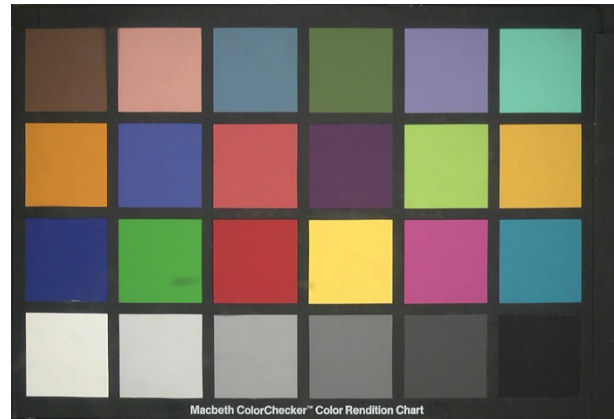


Figure 1 Colorchecker chart

### 2.2 Gamma curves

There are 5 normal gamma curves available in the camera, and two Cine curves. These curves appear to be very similar to those in other Panasonic cameras. *Norm1* was clearly intended to be the ITU.709 curve, and performs well. *Low* is the curve of the DVX100, *High* is probably the BBC 0.4 law which gives best colour rendition at the expense of a small increase in noise levels. *B.Press* compresses near black to increase perceived contrast and reduce noise near black. *Cine-likeD* is a good curve for producing a film look, with gentle compression of highlights and black but a long contrast range, *Cine-likeV* produces a more contrasty picture. Both the Cine curves work best if exposure is reduced somewhat, to avoid skin tones being distorted at high exposure.

No experiments were made with the Knee function, since it has very little control, but the camera can be expected to have at least 100% (1 stop) of exposure headroom.

### 2.3 Resolution

A HDTV zone plate chart was used. This contains six circular patterns which fully explore the spatial frequency performance of the camera, up to 1920x1080 pixels per width and height. There are patterns for grey-scale testing of luma performance, the others are coloured for examining chroma resolution or other colour filtering. Modulation is cosine rather than square wave. Each pattern is a “phase space” map of the possible frequencies that the camera can be expected to deal with, reaching 1920 pixels/picture width (960 cycles) horizontally, and 1080 lines/picture height (540 cycles) vertically.

#### 2.3.1 Resolution, 1080-line

Fig.2 shows a single quadrant of one pattern; for this exposure, the camera detail enhancement was set to the factory default value (0). There is a disturbing level of spatial aliasing, both horizontally and vertically, which is a clear indication that something odd is happening in the conversion from the native resolution of the sensor to the 1920x1080 output format.



The specification claims that the active sensor area is ‘approximately 17.8 x 10.0mm, 16:9’ and that there are approximately 12.4 million pixels. Assuming this to be the case, and after a few minutes with a spreadsheet, it would imply that the sensor pixel dimensions are approximately 4,692x2,640, which gives a total pixel count of 12,386,880. However, another (unpublished) Panasonic document states that the sensor is from a stills camera, and actually has 4:3 aspect ratio and therefore must have dimensions of 17.8 x 13.35mm, and it seems probable that the specification’s claim of 12.4 million pixels applies to this sensor and not to the 16:9 image area.

If the figure of 12.4 million pixels were to apply to only the active image area, then the down-scaling ratio to get to 1920x1080 would have to be  $4,692/1,920=2.443,75:1$ , which is a very strange number to have been chosen deliberately. The complete lack of coloured aliasing in Fig.1 is a clear proof that the resolution of the red and blue sub-patterns on the sensor are each greater than 1920x1080, and this calculation estimates that the actual pixel counts for R and B are 2346x1320. Thus, it is very odd to have such a high level of luma aliasing in the image, since there are plenty more pixels on the sensor than are needed to get to 1920x1080. It is very obvious that the scaling has not ignored (skipped) sensor pixels, since that would have invoked coloured aliasing, both horizontally and vertically.

If the 12.4 million pixel figure applies to the whole 4:3 sensor, then the pixel dimensions must be about 4068x3051, and the down-scaling factor 2.11875:1, again, a strange number to have chosen. In this case, the active area would have a pixel count of about 9.3 million.

The horizontal and vertical aliases have a centre frequency of 1.224 times the system frequencies. This implies that there is an underlying resolution 1.224 times that of 1920x1080, or 2350x1322, and this further implies that the sensor pixel dimensions are double that or 4700x2644, which is very close to my first estimate, that 12.4 million applies to the active image area.

Resolution is clean up to 63% of 1920x1080, where there are low-level null zones visible. This means that the image has clean resolution only up to 1210x680, which is not good, given the strength of the aliases.

Fig.3 shows the individual patterns for red and blue, and there is clearly very little difference between the two colours (blue should always be the same as red anyway), the levels of aliases are identical. This implies that the green signal has been derived from the sensor, at the same resolution as that of red and blue (which must be about 2350x1322 since the red and blue filters are present on alternate pixels and rows of a Bayer-patterned sensor), before being down-scaled to 1920x1080. It is also clear, from the double-frequency pattern in the middle, that the lens is passing frequencies up to nearly twice that of 1920x1080, since the vertical spatial alias reappears above the sensor resolution limit. This is an indication that there is either no optical low-pass filter, or that it is inadequate.

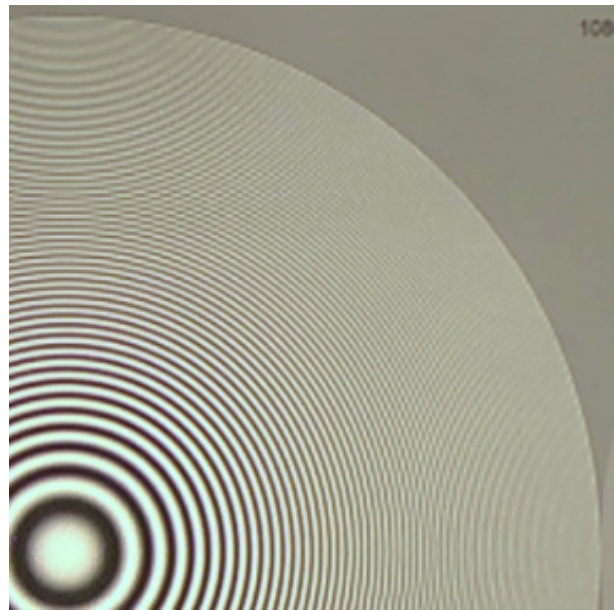


Figure 2 Zone plate 1080psf, luma pattern

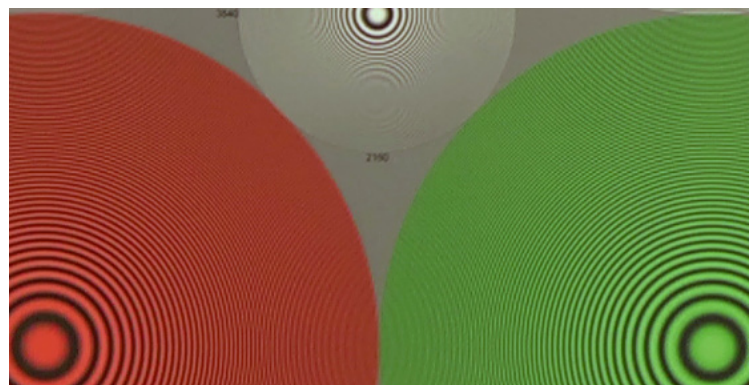


Figure 3 Zone plate 1080p, R, double frequency luma, G

The detail settings did not significantly improve the situation, the aliases dominated at all settings, however, setting vertical detail to -2 did look a little better. It seems possible that the detail level controls in this camera actually reduce detail with negative settings, an usual but welcome feature.

### 2.3.2 Resolution, 720p

The internal down-conversion to 1280x720 performs as expected, the clean resolution is unchanged, but there are horizontal and vertical null stripes at 1280 and 720 respectively. The performance of the down-converter is not bad in itself, but the high level of aliasing in the original image prevents performance at 720p from being acceptable.

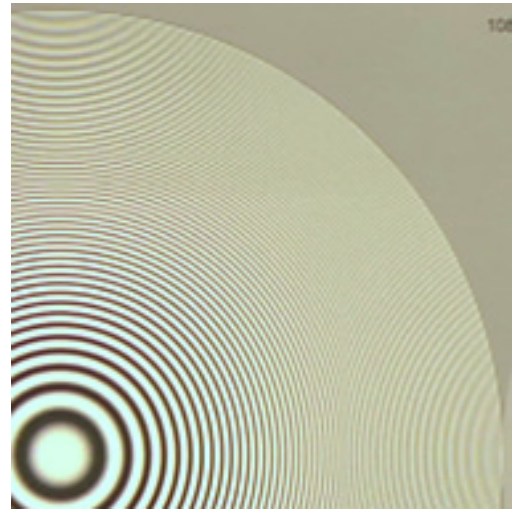


Figure 4 Zone plate 720p

### 2.4 Video Noise Levels

Video noise was measured by recording a white card, uniformly lit, and performing numerical analysis in software. The camera was set to 0dB gain, there was no need to use a higher gain setting. A software high-pass filter was used to remove all horizontal frequencies below about 5% of the nominal maximum of half-sampling frequency, thus eliminating the effects of any lighting shading.

The distribution of noise levels nicely follows the expected curve, of increasing noise level as the video signal level falls. If the sole noise-source is the sensor itself (and/or the head amplifiers and ADCs), then the noise level at 10% video should be about 10dB higher than at 90%, which it clearly is. It is obvious that gamma-correction is done in the digital-signal domain, where it should be. The achieved figure of about -49dB (for luma at mid-grey) is quite good, but indicates that using high levels of camera gain is not a good idea.

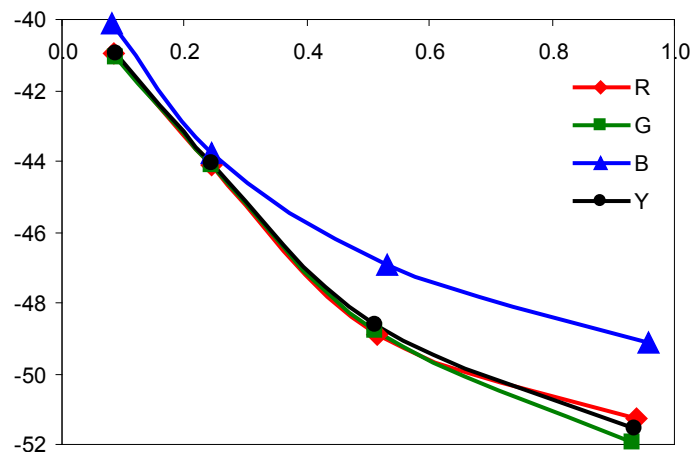


Figure 5 Video noise levels

The noise level from a sensor is a function of the pixel size. From the calculations done in section 2.3.1, the pixels must be sited at  $17,800/4,692=3.79\mu\text{m}$  intervals. For comparison, the pixel spacing of a normal  $\frac{1}{3}$ " HDTV camera with 3 1920x1080 pixel sensors is  $5\mu\text{m}$ , while that for a similar  $\frac{1}{2}$ " camera is  $3.75\mu\text{m}$  intervals. So, the sensitivity and noise performance of this camera should be similar to that of a  $\frac{1}{2}$ " camera rather than an ideal large-format camera.

### 2.5 Video Sensitivity

Sensitivity was measured directly. The card was exposed to a blank white card (the white, 90% reflectance, side of a Kodak gray card), illuminated at 2000lux. The camera was set to 25p with 1/50 shutter, with a conventional gamma curve (Norm1) and the aperture adjusted to achieve 100% video level. The lens indicator showed about  $\frac{1}{4}$  stop closed on F/8.0, probably about F/8.75. The specification claims, under the same lighting conditions, F/8.0 for operation at 59.94. The extra quarter stop is just right for the difference between exposing at 50Hz and 59.94Hz.

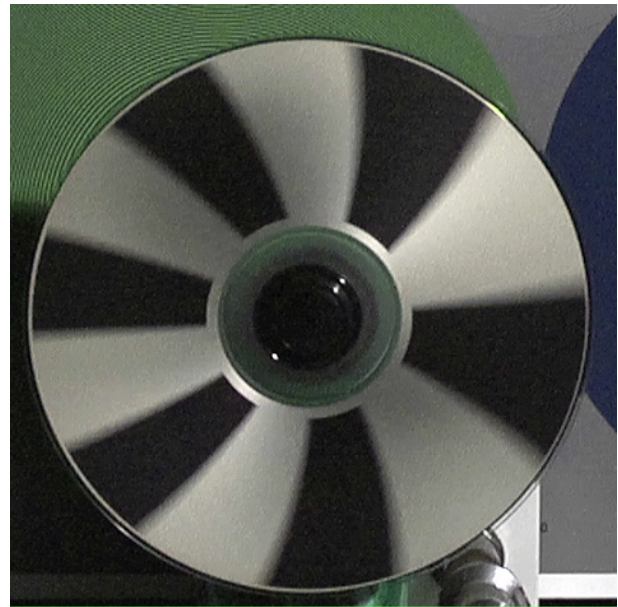
### 2.6 Shuttering and Motion



The camera has a CMOS sensor, and thus can be expected to exhibit the effects of a rolling shutter. This is easily demonstrated by using a rotating fan.

Figure 6 shows one frame of a small fan, six bladed, with symmetrical blades. The camera was set to a short shutter (about 1/1000, not critical) and the fan speed was adjusted to one of several critical speeds at which a stroboscopic effect was observed. The blades are compressed when on the left (going up, against the rolling shutter), expanded on the right (going down, overtaking the rolling shutter). The effect shown is not severe, and is a great deal better than most CMOS cameras exhibit. Clearly, something good has been done in the image processing to minimise the effects, the unpublished Panasonic document on the camera claims that 'high-speed scanning' has been used, clearly it works.

If the shutter is set to a more sensible speed then the effect is far less visible.



**Figure 6 Rolling shutter effect**

Figure 7 shows two complete frames captured from a test sequence to investigate further the secrets of this camera. The sequence was shot in the temporarily cluttered interior of my dining room, and consists of a series of pans across the window frames, at ever increasing speeds. The contrast is high, exacerbated by the black neoprene seals. The camera was set to shoot progressive at 25Hz, and with the settings in the tables. Two sequences were shot, with shutter durations of 1/50 second and 1/1000 second.



**Figure 7 Panning frames 21 and 22**

These two frames are from the second test, at 1/1000 second shutter. The pan speed is high, and can be calculated accurately by measuring the distance which an object (e.g. an upright of the window frame) moves between frames, in this case 8.9% of the image width. Therefore, an object would take 11.25 frames to exit one side after having entered at the other, a speed of 0.45 seconds per picture width. Technically, this constitutes a 'whip pan' and should not be expected to produce sensible pictures when played back a full speed. However, the individual images are sharp and clean, there is no hint of the sort of multiple imaging which would be expected had there been any inter-frame image processing in the camera.

The window frames lean against the motion due to the effect of the 'rolling shutter' (the camera is panning right-to-left, so the window is moving left-to-right). By overlaying the images and tracing the exact positions and slopes of the edge of one frame, it is possible to calculate the 'transit-time' of the shutter. We already know that the duration is 1/1000, but the transit-time is the time it takes to perform the exposure of the frame, and not the time for which each pixel is exposed. In a tubed camera this would always be the field interval (20ms for 50Hz, 40ms for 25Hz). Since the two images of the edge are displaced by 8.9% of picture width, all we need to know is what proportion of the picture height is occupied by a sloping line which traces the slope of the window edge, extended until its two ends are exactly 8.9% of the picture width apart, and this is measured as 157%. Therefore, the transit time of the shutter is 63.7% of the frame interval, or 25.5ms.

The camera promotional information claims ‘high-speed scanning’, and, presumably, this is what that claim means.

The other sequence, shot at 1/50s shutter, shows exactly the same effects, but the individual frames are much more blurred. When shown at normal playback speeds, these high-speed pans look very poor on pixel-based displays (LCD, plasma, etc), not because of any fault in the camera, but because the image has been recorded at 25Hz and the display is showing the images at 50Hz by repeating frame information, the classic ‘film-motion’ judder. When shown on a computer display, the effect is even worse, because the display is almost certainly performing a 2-3 pull-down conversion to show the material at the 60Hz native refresh rate of the display. None of this is any reflection on the camera, but on the shooting style, and on the form of display. No experience programme-maker would ever consider trying to shoot pans at such high speeds, simply because they visually highly disturbing.

A repeat experiment, to explore the effect in interlaced scanning, produced exactly the expected results. The two fields are separate exposures, and therefore show scenic detail two indifferent places. Poor de-interlacing algorithms (such as are common in low-cost computer and television displays) may well produce pictures with double images from this, but that is not a camera problem (it happens in all cameras), it’s a problem for the de-interlacer.

When shooting in a ‘film-style’ in is essential to know and observe the classic film rules of acceptable practices and panning speeds:



**Figure 8 small part of interlaced pan, high speed**

- **Slow pan:** in which an object takes 8 seconds or more to exit one side after entering the other (the pan transit-time), looks ‘gritty’ in that something is clearly going on but it isn’t disturbing.
- **Whip pan:** in which an object takes one second or less to perform the horizontal transit, should look blurred, but can be made to look really poor when a short shutter is used.
- **Worst pan:** in which an object takes about 3 seconds to perform the transit. The gives rise to confusion in the eye, which cannot fuse together the two presentations of the repeated frames, and ‘sees’ two objects moving together rather than one. When such an object is made excessively sharp, either by using a short shutter or excessive detail enhancement, or both, then the effect can be made dramatically worse.

## 2.7 Conclusion

This camera does not perform particularly well at HD. Clean resolution is limited to about 1210x680 by the presence of high-amplitude spatial aliasing. This is a little disappointing from a camera with a large-format sensor, and indicates that optical low-pass filtering is either absent or inadequate, and that the scaling from the resolution of the sensor down to 1920x1080 has not been done in the best way.

Noise levels are rather high, even though the pixel size is that of a conventional 3 sensor 1/2” camera. Sensitivity is also similar to that of a 1/2” camera.

If this camera is to be used for HDTV shooting, then it should be clearly understood that it’s only advantage over smaller-format cameras is the smaller depth of field. However, to achieve a smaller depth of field in this camera, relative to, say, a 1/2” camera, then the lens must be opened by at least 1.5 stops; using an F/2.8 lens on this camera, wide open, will give the same depth of field as on a 1/2” camera with a lens opened to

F/1.6. This camera will not necessarily always deliver short depth of field, large aperture lenses must be used to achieve that.