# Week 2.1 Linearity

Rod Hughes

Determining the linearity of your camera is an important step in performing quality photometry whether you have an ABG camera or a NABG CCD or a cMOS camera. So, the first task this week is to determine your linearity limits.

**1a. Is your camera NABG or ABG?**

Rod: My QSI683 CCD camera is ABG (auto-blooming gate)

**What are your linearity limits? For example, My Atik4000 is an ABG camera and becomes non-linear around 50K ADU. My NABG Moravian 1600 becomes non-linear around 55KADU. Now measure the linearity of your camera and share your finding with us.**

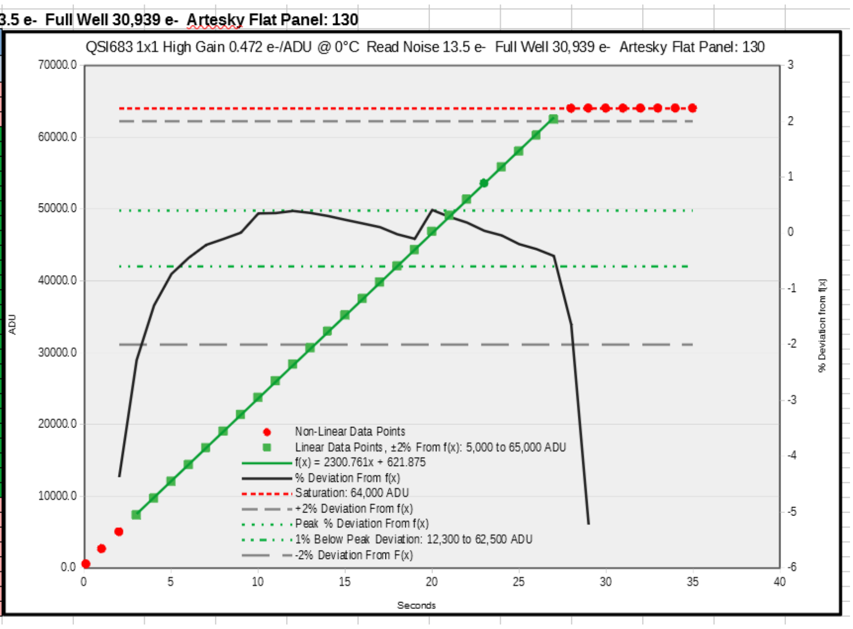
Rod: This is my first attempt at performing linearity tests on the QSI683 CCD camera, bin 1x1, temperature 0°C. The camera was mounted on OTA and a Luminance filter was used. Saturation was determined by a 30-second exposure and adjusting Artesky flat panel illumination. First measurements made at 0.1 seconds and then at 1-second intervals. This was performed at night in a darkened observatory.

PixInsight was used to find the mean and standard deviation 16-bit ADU values for center 100 by 100 pixels. Data was entered into a spreadsheet for analysis. Notice how Std Dev rapidly falls off when approaching saturation. Some linear interpolation was required to determin 1% linearity from 12,300 to 62,500 ADU. Would like to repeat measurements with out OTA and filter. Not sure why there was weird change in mean value around 20-seconds. This needs to be investigated.

First time process is always interesting because it is a learning/discovery process. Considerable effort was spent on the analysis. However, future analysis should be much faster.

**QSI683 1x1 High Gain 0.472 e-/ADU @ 0°C Read Noise 13.5 e- Full Well 30,939 e- Artesky Flat Panel: 130**

| Exposure Time In Seconds | PixInsight Statistics from Center area 750x750 pixel | | Calculations | | |
|---|---|---|---|---|---|
| | Mean ADU | Std Dev | f(x) | deviation from f(x) | % linear |
| 0.1 | 511.3 | 36.5 | 852.0 | -340.7 | -66.6 |
| 1 | 2650.5 | 79.3 | 2922.6 | -272.1 | -10.3 |
| 2 | 5004.6 | 107.3 | 5223.4 | -218.8 | -4.4 |
| 3 | 7356.6 | 128.5 | 7524.2 | -167.6 | -2.3 |
| 4 | 9698.9 | 150.1 | 9824.9 | -126.0 | -1.3 |
| 5 | 12037.1 | 166.4 | 12125.7 | -88.6 | -0.7 |
| 6 | 14362.6 | 180.2 | 14426.4 | -63.8 | -0.4 |
| 7 | 16691.4 | 197.0 | 16727.2 | -35.8 | -0.2 |
| 8 | 19007.4 | 211.6 | 19028.0 | -20.6 | -0.1 |
| 9 | 21329.8 | 223.8 | 21328.7 | 1.1 | 0.0 |
| 10 | 23712.2 | 236.6 | 23629.5 | 82.7 | 0.3 |
| 11 | 26022.8 | 248.4 | 25930.2 | 92.6 | 0.4 |
| 12 | 28342.5 | 260.5 | 28231.0 | 111.5 | 0.4 |
| 13 | 30641.4 | 269.5 | 30531.8 | 109.6 | 0.4 |
| 14 | 32932.5 | 285.1 | 32832.5 | 100.0 | 0.3 |
| 15 | 35216.0 | 294.7 | 35133.3 | 82.7 | 0.2 |
| 16 | 37497.6 | 306.4 | 37434.1 | 63.5 | 0.2 |
| 17 | 39775.8 | 315.5 | 39734.8 | 41.0 | 0.1 |
| 18 | 42025.1 | 320.7 | 42035.6 | -10.5 | 0.0 |
| 19 | 44289.6 | 331.8 | 44336.3 | -46.7 | -0.1 |
| 20 | 46829.8 | 345.1 | 46637.1 | 192.7 | 0.4 |
| 21 | 49078.7 | 350.1 | 48937.9 | 140.8 | 0.3 |
| 22 | 51333.9 | 359.9 | 51238.6 | 95.3 | 0.2 |
| 23 | 53559.9 | 366.0 | 53539.4 | 20.5 | 0.0 |
| 24 | 55815.1 | 377.8 | 55840.1 | -25.0 | 0.0 |
| 25 | 58024.4 | 384.9 | 58140.9 | -116.5 | -0.2 |
| 26 | 60267.1 | 388.4 | 60441.7 | -174.6 | -0.3 |
| 27 | 62484.1 | 402.3 | 62742.4 | -258.3 | -0.4 |
| 28 | 63992.7 | 9.1 | 65043.2 | -1050.5 | -1.6 |
| 29 | 64000.0 | 0.0 | 67343.9 | -3343.9 | -5.2 |
| 30 | 64000.0 | 0.0 | 69644.7 | -5644.7 | -8.8 |
| 31 | 64000.0 | 0.0 | 71945.5 | -7945.5 | -12.4 |
| 32 | 64000.0 | 0.0 | 74246.2 | -10246.2 | -16.0 |
| 33 | 64000.0 | 0.0 | 76547.0 | -12547.0 | -19.6 |
| 34 | 64000.0 | 0.0 | 78847.8 | -14847.8 | -23.2 |
| 35 | 64000.0 | 0.0 | 81148.5 | -17148.5 | -26.8 |



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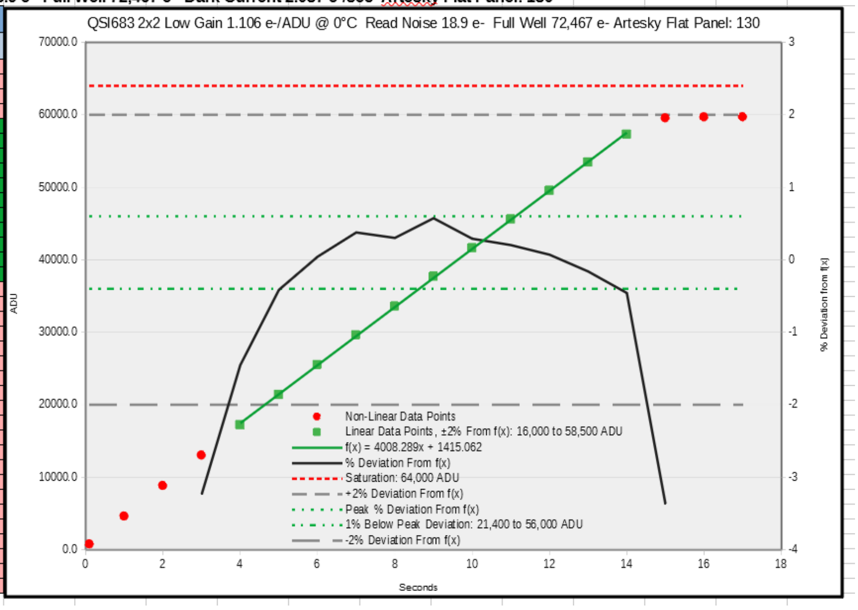
Measurements were also acquired with camera set to 2x2 binning which is a better match for my skies and telescope.

Need more sample points. It would be interesting to perform several sets of measurements to determine an average. Now that I have learned the process it shouldn't be too difficult. Look at the data from 14-seconds to 35 seconds. Looks like ABG is working hard to prevent saturation until it finally gives up at 33-seconds.

**QSI683 2x2 Low Gain 1.106 e-/ADU @ 0°C Read Noise 18.9 e- Full Well 72,467 e- Dark Current 2.037 e-/sec Artesky Flat Panel: 130**

| Exposure Time In Seconds | PixInsight Statistics from Center area 750x750 pixel | | Calculations | | |
|---|---|---|---|---|---|
| | Linear Mean ADU | Std Dev | f(x) | deviation from f(x) | % linear |
| 0.1 | 754.3 | 27.2 | 1815.9 | -1061.6 | -140.7 |
| 1 | 4597.5 | 69.0 | 5423.4 | -825.9 | -18.0 |
| 2 | 8816.3 | 94.7 | 9431.6 | -615.3 | -7.0 |
| 3 | 13018.3 | 114.6 | 13439.9 | -421.6 | -3.2 |
| 4 | 17198.3 | 133.1 | 17448.2 | -249.9 | -1.5 |
| 5 | 21368.0 | 151.1 | 21456.5 | -88.5 | -0.4 |
| 6 | 25475.5 | 164.1 | 25464.8 | 10.7 | 0.0 |
| 7 | 29584.5 | 178.3 | 29473.1 | 111.4 | 0.4 |
| 8 | 33582.5 | 190.6 | 33481.4 | 101.1 | 0.3 |
| 9 | 37705.7 | 200.0 | 37489.7 | 216.0 | 0.6 |
| 10 | 41618.7 | 215.1 | 41498.0 | 120.7 | 0.3 |
| 11 | 45598.6 | 222.4 | 45506.2 | 92.4 | 0.2 |
| 12 | 49549.3 | 232.2 | 49514.5 | 34.8 | 0.1 |
| 13 | 53436.5 | 239.0 | 53522.8 | -86.3 | -0.2 |
| 14 | 57268.7 | 236.9 | 57531.1 | -262.4 | -0.5 |
| 15 | 59531.8 | 54.3 | 61539.4 | -2007.6 | -3.4 |
| 16 | 59668.5 | 44.6 | 65547.7 | -5879.2 | -9.9 |
| 17 | 59679.8 | 45.0 | 69556.0 | -9876.2 | -16.5 |
| 18 | 59676.0 | 45.0 | 73564.3 | -13888.3 | -23.3 |
| 19 | 59677.7 | 44.8 | 77572.6 | -17894.9 | -30.0 |
| 20 | 59674.2 | 44.4 | 81580.8 | -21906.6 | -36.7 |
| 21 | 59673.6 | 44.8 | 85589.1 | -25915.5 | -43.4 |
| 22 | 59673.5 | 44.9 | 89597.4 | -29923.9 | -50.1 |
| 23 | 59676.5 | 44.3 | 93605.7 | -33929.2 | -56.9 |
| 24 | 59670.1 | 45.1 | 97614.0 | -37943.9 | -63.6 |
| 25 | 59669.6 | 44.8 | 101622.3 | -41952.7 | -70.3 |
| 26 | 59667.8 | 45.0 | 105630.6 | -45962.8 | -77.0 |
| 27 | 59664.1 | 45.3 | 109638.9 | -49974.8 | -83.8 |
| 28 | 59662.8 | 44.4 | 113647.2 | -53984.4 | -90.5 |
| 29 | 59661.5 | 44.9 | 117655.4 | -57993.9 | -97.2 |
| 30 | 59664.1 | 44.4 | 121663.7 | -61999.6 | -103.9 |
| 31 | 59666.2 | 45.3 | 125672.0 | -66005.8 | -110.6 |
| 32 | 59662.1 | 44.6 | 129680.3 | -70018.2 | -117.4 |
| 33 | 64000.0 | 0.0 | 133688.6 | -69688.6 | -108.9 |
| 34 | 64000.0 | 0.0 | 137696.9 | -73696.9 | -115.2 |
| 35 | 64000.0 | 0.0 | 141705.2 | -77705.2 | -121.4 |

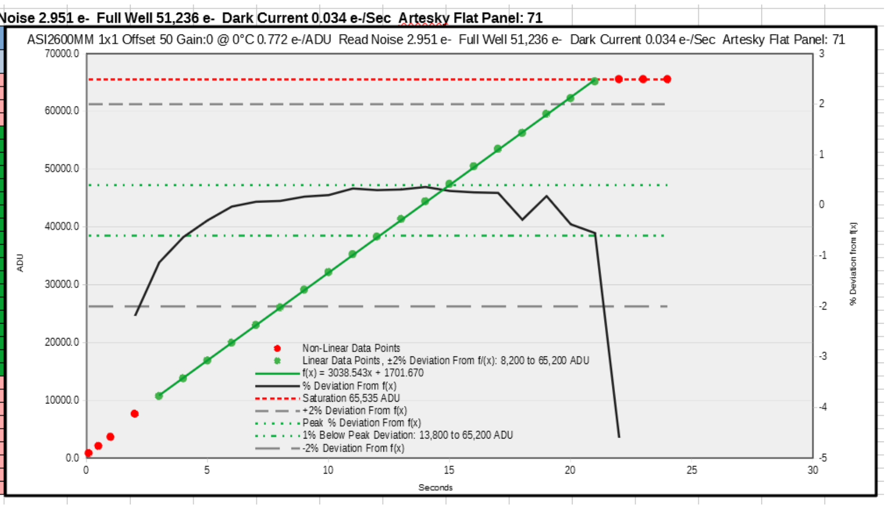



**1b. Or what are your linearity limits of your CMOS camera? My little ASI183MM goes to 60K ADU.**

Rod: Made some measurement on a ZWO ASI2600MM CMOS camera. The camera was suspended 7" above the flat panel. Measurements were made in a very dark room for 1x1 and 2x2 binning.

**ASI2600MM 1x1 Offset 50 Gain:0 @ 0°C 0.772 e-/ADU Read Noise 2.951 e- Full Well 51,236 e- Dark Current 0.034 e-/Sec Artesky Flat Panel: 71**

| Exposure Time In Seconds | PixInsight Statistics from Center area: 100 x 100 pixels | | Calculations | | |
|---|---|---|---|---|---|
| | Mean ADU | StdDev | f(x) | deviation from f(x) | Deviation % linear |
| 0.1 | 806.9 | 21.0 | 2005.5 | -1198.6 | -148.5 |
| 0.5 | 2039.5 | 44.3 | 3220.9 | -1181.4 | -57.9 |
| 1 | 3617.2 | 63.3 | 4740.2 | -1123.0 | -31.0 |
| 2 | 7612.0 | 97.3 | 7778.8 | -166.8 | -2.2 |
| 3 | 10696.3 | 115.2 | 10817.3 | -121.0 | -1.1 |
| 4 | 13769.4 | 136.2 | 13855.8 | -86.4 | -0.6 |
| 5 | 16844.4 | 150.6 | 16894.4 | -50.0 | -0.3 |
| 6 | 19928.0 | 163.9 | 19932.9 | -4.9 | 0.0 |
| 7 | 22987.7 | 175.9 | 22971.5 | 16.2 | 0.1 |
| 8 | 26032.5 | 190.2 | 26010.0 | 22.5 | 0.1 |
| 9 | 29098.5 | 202.3 | 29048.6 | 49.9 | 0.2 |
| 10 | 32152.1 | 214.7 | 32087.1 | 65.0 | 0.2 |
| 11 | 35242.8 | 228.9 | 35125.6 | 117.2 | 0.3 |
| 12 | 38279.3 | 233.1 | 38164.2 | 115.1 | 0.3 |
| 13 | 41332.4 | 248.4 | 41202.7 | 129.7 | 0.3 |
| 14 | 44402.3 | 259.7 | 44241.3 | 161.0 | 0.4 |
| 15 | 47414.8 | 264.2 | 47279.8 | 135.0 | 0.3 |
| 16 | 50447.4 | 274.8 | 50318.4 | 129.0 | 0.3 |
| 17 | 53488.1 | 290.6 | 53356.9 | 131.2 | 0.2 |
| 18 | 56235.5 | 297.0 | 56395.4 | -159.9 | -0.3 |
| 19 | 59543.0 | 304.6 | 59434.0 | 109.0 | 0.2 |
| 20 | 62238.7 | 311.7 | 62472.5 | -233.8 | -0.4 |
| 21 | 65153.2 | 243.9 | 65511.1 | -357.9 | -0.5 |
| 22 | 65535.0 | 0.0 | 68549.6 | -3014.6 | -4.6 |
| 23 | 65535.0 | 0.0 | 71588.2 | -6053.2 | -9.2 |
| 24 | 65535.0 | 0.0 | 74626.7 | -9091.7 | -13.9 |
| 25 | 65535.0 | 0.0 | 77665.2 | -12130.2 | -18.5 |
| 26 | 65535.0 | 0.0 | 80703.8 | -15168.8 | -23.1 |
| 27 | 65535.0 | 0.0 | 83742.3 | -18207.3 | -27.8 |
| 28 | 65535.0 | 0.0 | 86780.9 | -21245.9 | -32.4 |
| 29 | 65535.0 | 0.0 | 89819.4 | -24284.4 | -37.1 |
| 30 | 65535.0 | 0.0 | 92858.0 | -27323.0 | -41.7 |



# Week 2.1 Linearity

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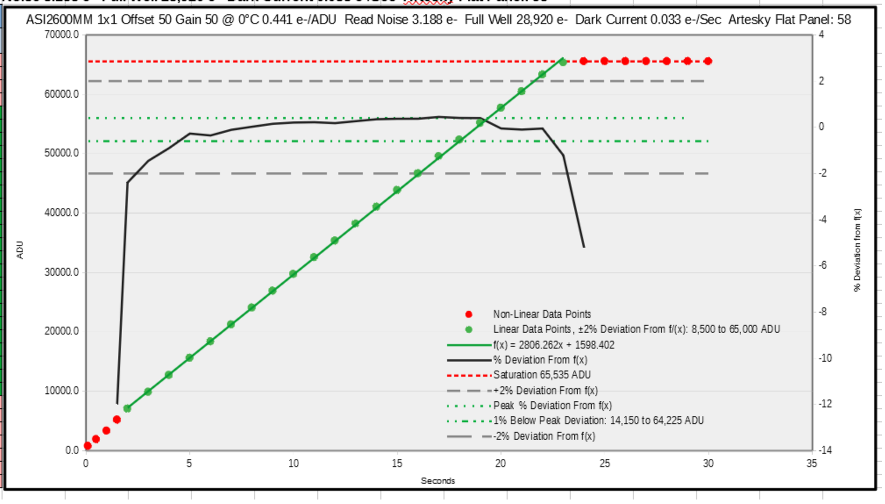
**ASI2600MM 1x1 Offset 50 Gain 50 @ 0°C 0.441 e-/ADU Read Noise 3.188 e- Full Well 28,920 e- Dark Current 0.033 e-/Sec Artesky Flat Panel: 58**

| Exposure Time In Seconds | PixInsight Statistics from Center area: 100 x 100 pixels | | Calculations | | |
|---|---|---|---|---|---|
| | Mean ADU | StdDev | f(x) | deviation from f(x) | % linear |
| 0.1 | 774.7 | 27.0 | 1879.0 | -1104.3 | -142.5 |
| 0.5 | 1904.6 | 57.4 | 3001.5 | -1096.9 | -57.6 |
| 1 | 3329.7 | 82.8 | 4404.7 | -1075.0 | -32.3 |
| 1.5 | 5186.0 | 103.8 | 5807.8 | -621.8 | -12.0 |
| 2 | 7042.3 | 124.7 | 7210.9 | -168.6 | -2.4 |
| 3 | 9873.7 | 146.9 | 10017.2 | -143.5 | -1.5 |
| 4 | 12708.7 | 169.1 | 12823.5 | -114.8 | -0.9 |
| 5 | 15587.4 | 190.9 | 15629.7 | -42.3 | -0.3 |
| 6 | 18370.9 | 205.1 | 18436.0 | -65.1 | -0.4 |
| 7 | 21219.0 | 223.8 | 21242.2 | -23.2 | -0.1 |
| 8 | 24054.4 | 238.9 | 24048.5 | 5.9 | 0.0 |
| 9 | 26895.5 | 250.4 | 26854.8 | 40.7 | 0.2 |
| 10 | 29721.9 | 268.2 | 29661.0 | 60.9 | 0.2 |
| 11 | 32538.3 | 280.4 | 32467.3 | 71.0 | 0.2 |
| 12 | 35336.8 | 294.8 | 35273.5 | 63.3 | 0.2 |
| 13 | 38181.1 | 307.8 | 38079.8 | 101.3 | 0.3 |
| 14 | 41029.3 | 317.8 | 40886.1 | 143.2 | 0.3 |
| 15 | 43854.0 | 331.7 | 43692.3 | 161.7 | 0.4 |
| 16 | 46671.6 | 343.0 | 46498.6 | 173.0 | 0.4 |
| 17 | 49526.9 | 355.2 | 49304.9 | 222.0 | 0.4 |
| 18 | 52322.9 | 364.2 | 52111.1 | 211.8 | 0.4 |
| 19 | 55136.8 | 373.5 | 54917.4 | 219.4 | 0.4 |
| 20 | 57694.1 | 382.1 | 57723.6 | -29.5 | -0.1 |
| 21 | 60469.7 | 388.9 | 60529.9 | -60.2 | -0.1 |
| 22 | 63302.5 | 400.5 | 63336.2 | -33.7 | -0.1 |
| 23 | 65349.1 | 162.6 | 66142.4 | -793.3 | -1.2 |
| 24 | 65535.0 | 0.0 | 68948.7 | -3413.7 | -5.2 |
| 25 | 65535.0 | 0.0 | 71755.0 | -6220.0 | -9.5 |
| 26 | 65535.0 | 0.0 | 74561.2 | -9026.2 | -13.8 |
| 27 | 65535.0 | 0.0 | 77367.5 | -11832.5 | -18.1 |
| 28 | 65535.0 | 0.0 | 80173.7 | -14638.7 | -22.3 |
| 29 | 65535.0 | 0.0 | 82980.0 | -17445.0 | -26.6 |
| 30 | 65535.0 | 0.0 | 85786.3 | -20251.3 | -30.9 |



# Week 2.1 Linearity

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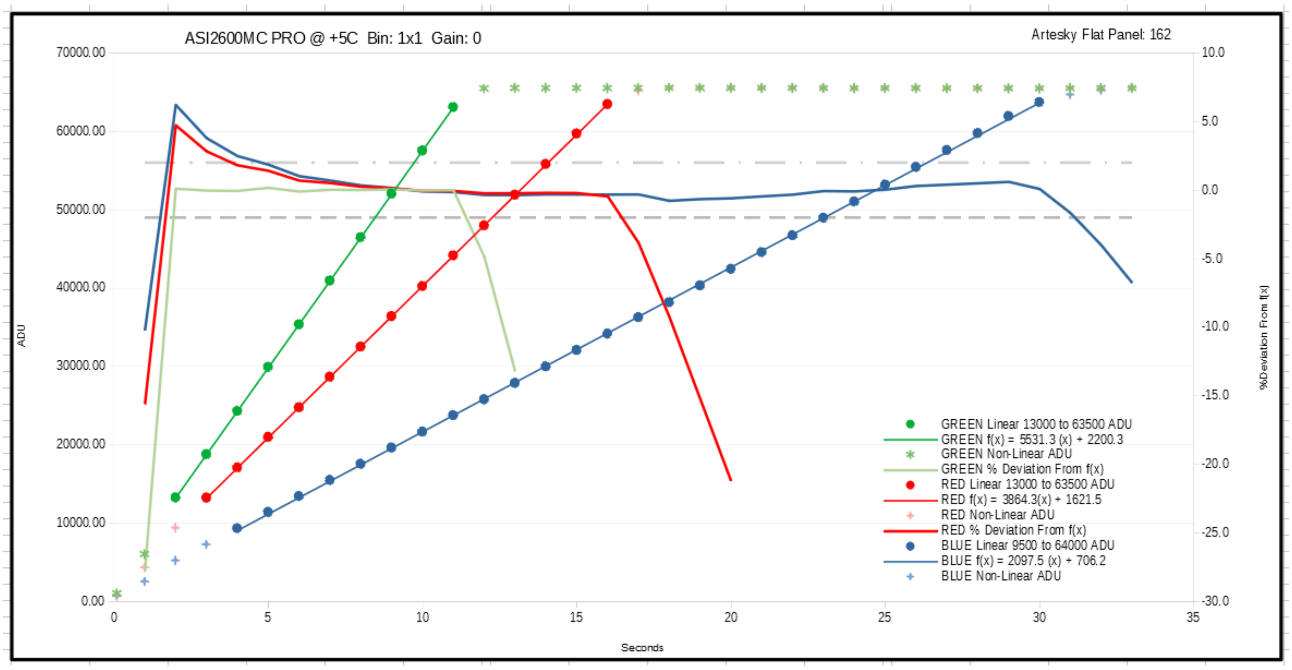
Also made some measurements on an ASI2600MC OSC CMOS camera.

**ASI2600MC 1x1 Low Gain:0 @ 5°C** **Artesky Flat Panel: 162**

| Exposure Time In Seconds | PixInsight Statistics from Center area 750x750 pixel | | Calculations | | | PixInsight Statistics from Center area 750x750 pixel | | Calculations | | | PixInsight Statistics from Center area 750x750 pixel | | Calculations | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean ADU | AvgDev | f(x) | deviation from f(x) | % linear | Mean ADU | AvgDev | f(x) | deviation from f(x) | % linear | Mean ADU | AvgDev | f(x) | deviation from f(x) | % linear |
| 0.1 | 884.41 | 23.41 | 2007.9 | -1123.5 | -127.0 | 1048.96 | 24.98 | 2747.4 | -1698.4 | -161.9 | 702.13 | 19.78 | 932.0 | -229.9 | -32.7 |
| 1 | 4370.41 | 118.00 | 5052.3 | -681.9 | -15.6 | 6047.78 | 155.50 | 7726.2 | -1678.5 | -27.8 | 2557.68 | 79.51 | 2819.0 | -261.3 | -10.2 |
| 2 | 9405.83 | 244.28 | 8962.6 | 443.2 | 4.7 | 13271.80 | 339.31 | 13258.3 | 13.5 | 0.1 | 5241.04 | 152.99 | 4915.6 | 325.4 | 6.2 |
| 3 | 13245.86 | 340.10 | 12872.9 | 373.0 | 2.8 | 18782.56 | 479.70 | 18790.4 | -7.8 | 0.0 | 7287.90 | 207.54 | 7012.3 | 275.6 | 3.8 |
| 4 | 17091.80 | 436.47 | 16783.2 | 308.6 | 1.8 | 24306.80 | 620.85 | 24322.5 | -15.7 | -0.1 | 9340.38 | 262.26 | 9108.9 | 231.5 | 2.5 |
| 5 | 20988.70 | 534.40 | 20693.5 | 295.2 | 1.4 | 29903.20 | 864.91 | 29854.6 | 48.6 | 0.2 | 11416.94 | 317.33 | 11205.6 | 211.4 | 1.9 |
| 6 | 24775.43 | 629.81 | 24603.8 | 171.6 | 0.7 | 35348.44 | 902.47 | 35386.7 | -38.2 | -0.1 | 13438.31 | 370.77 | 13302.2 | 136.1 | 1.0 |
| 7 | 28660.64 | 726.76 | 28514.1 | 146.5 | 0.5 | 40927.37 | 1043.74 | 40918.7 | 8.6 | 0.0 | 15506.79 | 425.52 | 15398.9 | 107.9 | 0.7 |
| 8 | 32504.66 | 823.65 | 32424.4 | 80.2 | 0.2 | 46450.94 | 1187.68 | 46450.8 | 0.1 | 0.0 | 17555.18 | 479.94 | 17495.5 | 59.7 | 0.3 |
| 9 | 36379.36 | 920.33 | 36334.7 | 44.6 | 0.1 | 52010.02 | 1322.65 | 51982.9 | 27.1 | 0.1 | 19621.93 | 534.44 | 19592.2 | 29.8 | 0.2 |
| 10 | 40224.89 | 1016.51 | 40245.0 | -20.1 | -0.1 | 57497.86 | 1459.42 | 57515.0 | -17.1 | 0.0 | 21667.82 | 587.90 | 21688.8 | -21.0 | -0.1 |
| 11 | 44127.17 | 1114.37 | 44155.3 | -28.2 | -0.1 | 63041.49 | 1579.60 | 63047.1 | -5.6 | 0.0 | 23750.88 | 643.33 | 23785.5 | -34.6 | -0.1 |
| 12 | 47950.30 | 1195.41 | 48065.6 | -115.3 | -0.2 | 65405.73 | 126.81 | 68579.2 | -3173.4 | -4.9 | 25789.55 | 671.43 | 25882.1 | -92.6 | -0.4 |
| 13 | 51852.74 | 1292.55 | 51975.9 | -123.2 | -0.2 | 65460.11 | 62.41 | 74111.2 | -8651.1 | -13.2 | 27875.79 | 726.00 | 27978.8 | -103.0 | -0.4 |
| 14 | 55771.62 | 1388.36 | 55886.2 | -114.6 | -0.2 | 65456.89 | 65.09 | 79643.3 | -14186.4 | -21.7 | 29979.14 | 780.94 | 30075.4 | -96.3 | -0.3 |
| 15 | 59665.43 | 1482.67 | 59796.5 | -131.1 | -0.2 | 65453.22 | 67.73 | 85175.4 | -19722.2 | -30.1 | 32067.32 | 836.37 | 32172.0 | -104.7 | -0.3 |
| 16 | 63415.27 | 1490.45 | 63706.8 | -291.6 | -0.5 | 65452.22 | 69.23 | 90707.5 | -25255.3 | -38.6 | 34155.62 | 888.61 | 34268.7 | -113.1 | -0.3 |
| 17 | 65114.10 | 471.84 | 67617.1 | -2503.1 | -3.8 | 65468.76 | 57.77 | 96239.6 | -30770.8 | -47.0 | 36248.03 | 941.21 | 36365.3 | -117.3 | -0.3 |
| 18 | 65473.01 | 54.31 | 71527.5 | -6054.4 | -9.2 | 65472.99 | 54.32 | 101771.7 | -36298.7 | -55.4 | 38162.39 | 991.83 | 38462.0 | -299.6 | -0.8 |
| 19 | 65470.45 | 56.53 | 75437.8 | -9967.3 | -15.2 | 65470.45 | 56.53 | 107303.8 | -41833.3 | -63.9 | 40291.76 | 1049.07 | 40558.6 | -266.9 | -0.7 |
| 20 | 65467.42 | 59.13 | 79348.1 | -13880.6 | -21.2 | 65467.42 | 59.13 | 112835.8 | -47368.4 | -72.4 | 42400.13 | 1103.86 | 42655.3 | -255.1 | -0.6 |
| 21 | 65463.76 | 62.32 | 83258.4 | -17794.6 | -27.2 | 65463.76 | 62.32 | 118367.9 | -52904.2 | -80.8 | 44545.51 | 1161.36 | 44751.9 | -206.4 | -0.5 |
| 22 | 65459.91 | 65.60 | 87168.7 | -21708.8 | -33.2 | 65459.91 | 65.60 | 123900.0 | -58440.1 | -89.3 | 46692.11 | 1217.37 | 46848.6 | -156.5 | -0.3 |
| 23 | 65455.84 | 69.12 | 91079.0 | -25623.1 | -39.1 | 65455.84 | 69.12 | 129432.1 | -63976.3 | -97.7 | 48910.00 | 1271.94 | 48945.2 | -35.2 | -0.1 |
| 24 | 65451.61 | 72.71 | 94989.3 | -29537.7 | -45.1 | 65451.61 | 72.71 | 134964.2 | -69512.6 | -106.2 | 50992.25 | 1327.79 | 51041.9 | -49.6 | -0.1 |
| 25 | 65447.29 | 60.04 | 98899.6 | -33452.3 | -51.1 | 65447.29 | 76.41 | 140496.3 | -75049.0 | -114.7 | 53153.59 | 1383.32 | 53138.5 | 15.1 | 0.0 |
| 26 | 65442.80 | 80.22 | 102809.9 | -37367.1 | -57.1 | 65442.80 | 80.22 | 146028.3 | -80585.5 | -123.1 | 55398.37 | 1440.38 | 55235.2 | 163.2 | 0.3 |
| 27 | 65438.29 | 84.11 | 106720.2 | -41281.9 | -63.1 | 65438.29 | 84.11 | 151560.4 | -86122.1 | -131.6 | 57557.31 | 1497.70 | 57331.8 | 225.5 | 0.4 |
| 28 | 65433.77 | 87.94 | 110630.5 | -45196.7 | -69.1 | 65433.77 | 87.94 | 157092.5 | -91658.7 | -140.1 | 59721.99 | 1552.66 | 59428.5 | 293.5 | 0.5 |
| 29 | 65429.31 | 91.69 | 114540.8 | -49111.5 | -75.1 | 65429.31 | 91.69 | 162624.6 | -97195.3 | -148.6 | 61893.63 | 1607.57 | 61525.1 | 368.5 | 0.6 |
| 30 | 65432.22 | 89.78 | 118451.1 | -53018.9 | -81.0 | 65432.22 | 89.78 | 168156.7 | -102724.5 | -157.0 | 63674.12 | 1417.82 | 63621.8 | 52.4 | 0.1 |
| 31 | 65436.92 | 86.10 | 122361.4 | -56924.5 | -87.0 | 65436.92 | 86.10 | 173688.8 | -108251.8 | -165.4 | 64635.87 | 801.09 | 65718.4 | -1082.5 | -1.7 |
| 32 | 65446.47 | 78.28 | 126271.7 | -60825.2 | -92.9 | 65446.47 | 78.28 | 179220.8 | -113774.4 | -173.8 | 65195.32 | 365.52 | 67815.0 | -2619.7 | -4.0 |
| 33 | 65457.03 | 67.40 | 130182.0 | -64725.0 | -98.9 | 65457.03 | 67.40 | 184752.9 | -119295.9 | -182.3 | 65486.54 | 52.87 | 69911.7 | -4425.2 | -6.8 |




Note how the Green channel saturates before the Red and Blue, having the lowest sensitivity, is last to saturate. Anyway, I thought it would be interesting to measure linearity on a OSC camera.

My strategy. I figure that with a ABG CCD I will start to go non-linear some where between 40k ADU and 55KADU. I also understand that CCD cameras have a non-linear range with very short

# Week 2.1 Linearity

Rod Hughes

exposures. So, depending on your light source see what you get with something like a 0.5 second exposure (or shorter if necessary). If the ADU count is low (100 ADU, for example), then begin doubling the exposure: 0.5, 1, 2, 4, 8, while watching the ADU count for each image. Once you get , say 35K ADU, you stop doubling: 9, 10, 11 or 10, 12, 14 depending on how fast you are increasing n ADU count. Again, watching the ADU count. When you get to 45K then pick something even finer, 1 second, 0,.5 second or whatever, again depending on the increase in ADU with each shot.

The strategy is to closely sample the ADU count as you move toward non-linearity. My suggestions above and only suggestions, it is the increase in ADU count of your sensor that is important.

Now the trick. Put your data into a spread sheet: two columns integration time and ADU count. Have a look at the plot with X being integration time and y being ADU count. You should see a fairly straight line until the line begins to bend. That is the point of non-linearity. So how to you really examine it?

Rod: I determined the non-linearity points by comparing measured results to values from a linear equation. The difference between measure value and linear value represents the degree of linearity. The dots on each chart represents measured data. The linear (straight) line on each chart is a graph of the linear equation. Also plotted is the linearity curve. I chose this approach to remove any subjectivity on what I thought to be linear verses a linear equation.

Fit a least-squares regression line only on those data that appear strictly linear. (up to 30K is probably safe, play around). Fit a line to those data, then extend the line upward. You should clearly see the break in the point that bend away from the straight line. An example by Simon Dawes at [https://britastro.org/node/22497](https://britastro.org/node/22497) is an excellent example of a linearity curve with the line-fit based only on the strictly linear data is attached.

Ed