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Results of WFC3 Thermal Vacuum Testing: IR Channel Gain

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ABSTRACT

Thermal vacuum testing in September - October of 2004 provided the fist opportunity to measure the gain of FPA64 since its integration into the instrument. Gain values derived from this data are between 2.43 e^-/ADU and 2.50 e^-/ADU, roughly 5% lower than those calculated for FPA64 at the Detector Characterization Lab (DCL).

Introduction

The on-orbit default gain setting for the IR channel is 2.5 e^-/ADU. The purpose of this test was to measure the exact gain for FPA64 now that it has been integrated into WFC3. Previous gain measurements were made on FPA64 at DCL, and revealed gain values of 2.62 - 2.63 e^-/ADU.

Data

The dataset used for this test contained 50 identical, 10-read, full frame ramps, taken with the SPARS10 sample sequence at the nominal on-orbit gain of 2.5 e^-/ADU. These data made up the IR02 test during thermal vacuum testing.

Analysis

Theory

The mean-variance method was used to calculate the gain from the IR02 data ramps. The description of this method below is reproduced from Bagget (2005). The mean-variance method assumes that the only sources of noise in the data are read noise, *RN*, and photon noise *P* (both in units of e^-). The total noise, *N*, in electrons, is then given by Equation 1, where *g* is the gain in units of e^-/ADU.

$$(N/g)^2 = (P/g)^2 + (RN/g)^2 \qquad 1)$$

Photon noise is the square root of the product of the mean signal, μ in ADU, and the gain. Also, the total observed variance will be in units of ADU^2, and is equal to the first term in Equation 1. Rewriting Equation 1 in a more convenient form gives Equation 2.

$$\sigma^2 = (1/g)*\mu + (RN/g)^2 \qquad 2)$$

Equation 2 shows that if the variance is plotted versus the mean signal, the resulting slope will be equal to the inverse of the gain. In order to remove pixel-to-pixel variation, as well as the effects of hot and dead pixels, the variance in this case was computed on a difference image. This increases the variance on the left side of Equation 2 by a factor of 2. To balance this, the mean signals were essentially doubled, as described in the next section. Twice the variance was then plotted versus twice the mean, forcing the slope to remain the inverse of the gain.

Implementation

All files were initially run through the IDL pre-processing pipeline (Hilbert, 2004), in order to remove bias signal and pixel-to-pixel variations in the zero level, as well as have the appropriate mask file applied. Dark current was also removed from each ramp by subtracting a previously computed SPARS10 dark current reference file.

After processing, gain values were calculated using a method identical to that used previously at DCL (DCL, 2004). The 50 files were split into 25 pairs. Each file was iteratively clipped 3 times at the 3σ level, in order to remove outliers. A difference ramp was created from each pair of input ramps. The variance of this difference image in each quadrant of each read was measured and recorded. In a method similar to that used to create the difference ramp, corresponding readouts from the two orignal ramps were summed in order to create a summed ramp. The mean signal level in each quadrant of each read of the summed ramp was calculated.

For each quadrant of the detector, a plot was made of the variance values versus the mean signal values. A best-fit line was then calculated for these points. The inverse of the slope of the best-fit line is then reported in Table 1 as the gain for FPA64. Three-sigma uncertainties in the best-fit line slope coefficients, and therefore the gain values, are 0.003 e^-/ADU. The plots, including best-fit lines, for each quadrant are shown in Figure 1.

Quad 1 (e^-/ADU)	**Quad 2 (e^-/ADU)**	**Quad 3 (e^-/ADU)**	**Quad 4 (e^-/ADU)**
2.43	2.50	2.46	2.47

Table 1. Gain values for each quadrant of FPA64. Errors (3-σ) are 0.003 e^-/ADU for each value.

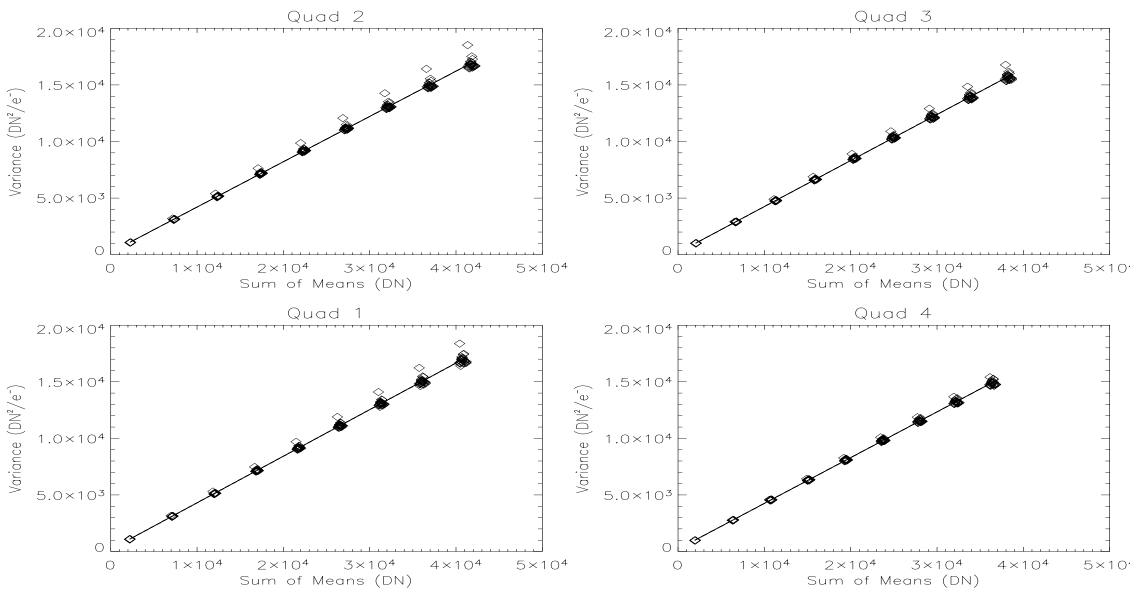

Figure 1: Mean-variance data and best-fit lines for all quadrants of FPA64. The slopes of the best-fit lines are the inverse of the gain values that are reported in Table 1.

Conclusions

The gain values for FPA64 calculated during thermal vacuum testing are ~5% below those calculated at DCL prior to integration into WFC3. Quadrant-averaged gain values range from 3% below, up to a match of the nominal on-orbit gain value of 2.5 e^-/pix.

The best-fit lines from Figure 1 also provide values of the readnoise. Unfortunately, the uncertainties in the readnoise values are large due to the uncertainties in the best-fit line coefficients. Beginning with these coefficients, which represent the third term in Equation 2, and calculating values for RN, 1σ uncertainties allowed for readnoise values anywhere between 21 e^-/pix and 25.5 e^-/pix. This is consistent with the higher values in the range of 19.5 e^-/pix to 22.5 e^-/pix calculated by Hilbert (2005).

References

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