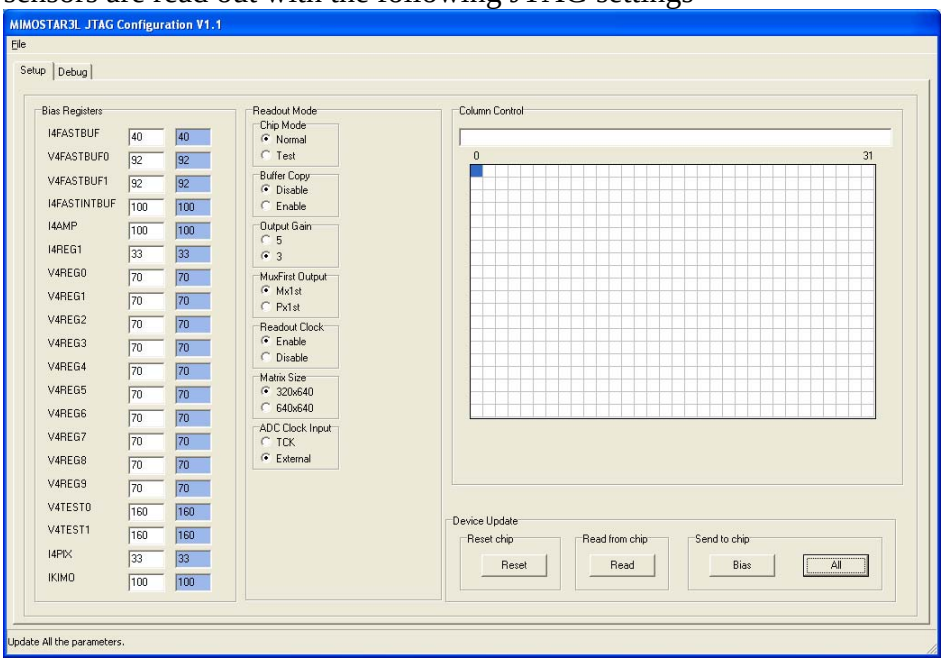
LG, XS, MS, HW
August 18, 2008 DRAFT

Results of the Mimostar-3 testing at LBNL (new fabrication run)

We have been testing the functionality and characteristics of the new fabrication run of Mimostar-3 sensors from AMS after the redesign and foundry process fixes that were initiated by the via connection problems in the previous Mimostar-3 fabrication. The sensors were initially tested at IPHC with probe testing and the leakage current and 1 light and 1 dark frame taken. The initial results are promising with the entire sensor sensitive to light and no dead areas of pixels in the centers of the sensors. We have completed individual testing of 9 Mimostar-3 sensors and a 1 Mimostar-2 sensor wire bonded to one of the Mimostar-3 testing board for comparison purposes. The results are presented below.

Testing Apparatus

After dicing, each Mimostar-3 is mounted to a testing board (schematic can be found at http://rnc.lbl.gov/hft/hardware/docs/pdf/Mimostar3_test_board.pdf) and wire bonded (bonding diagram can be found at http://rnc.lbl.gov/hft/hardware/docs/mimostar3_bonding_diagram.pdf). Each testing board is individually tested by attaching it to the prototype readout system used for the tests of Mimostar-2 based telescope. The schematics for this RDO system may be found at;
Motherboard => http://rnc.lbl.gov/hft/hardware/docs/rdo/mimostar2_mb_prelim_v4.pdf
Daughter card => http://rnc.lbl.gov/hft/hardware/docs/rdo/hft-daughterboard.pdf
STRATIX => http://rnc.lbl.gov/hft/hardware/docs/rdo/microtronix_stratix_revc.pdf
JTAG configuration and reset is done via the parallel port on a PC with the IRES JTAG configuration software. Clocks and sync are provided by the FPGA. The Mimostar-3 sensors are read out with the following JTAG settings



NOTE: Certain irregularities were noted during the testing that indicated that the testing system was not operating perfectly. The errors appear to have been corrected but the time critical nature of these measurements did not allow for the complete verification of all aspects of the testing system. We believe that what is presented is accurate, and that if errors are represented, they are very small and do not affect the conclusions.

Mimostar3 Calibration / Mimostar2 comparison

We calibrated three Mimostar3 sensors with an ^{55}Fe source and cross checked the results by calibrating a Mimostar2 mounted and wire-bonded to a Mimostar3 testing board. In this test, the internal DACs were terminated. All testing was done with a sensor temperature of 30 degrees C. The results are shown below.

Mimostar2

Sub-array	**gain**	**^{55}Fe peak (ADC)**	**e / ADC**	**RMS Noise (e)**
0	3	250	6.544	20
0	5	420	3.895	17.1
1	3	212	7.717	23.9
1	5	370	4.422	Data out of ADC range

These results are mostly consistent with the results obtained with the previous testing of Mimostar2 done at LBNL, though the noise is lower in this case due to the terminated DAC outputs.

Mimostar3 Performance

The inherent RDO system noise (with inputs to the Mimostar3 sensor disconnected at J4 and J12 of the testing board) gives a RMS of 1.24 ADC counts and is not considered a significant set of noise for these measurements.

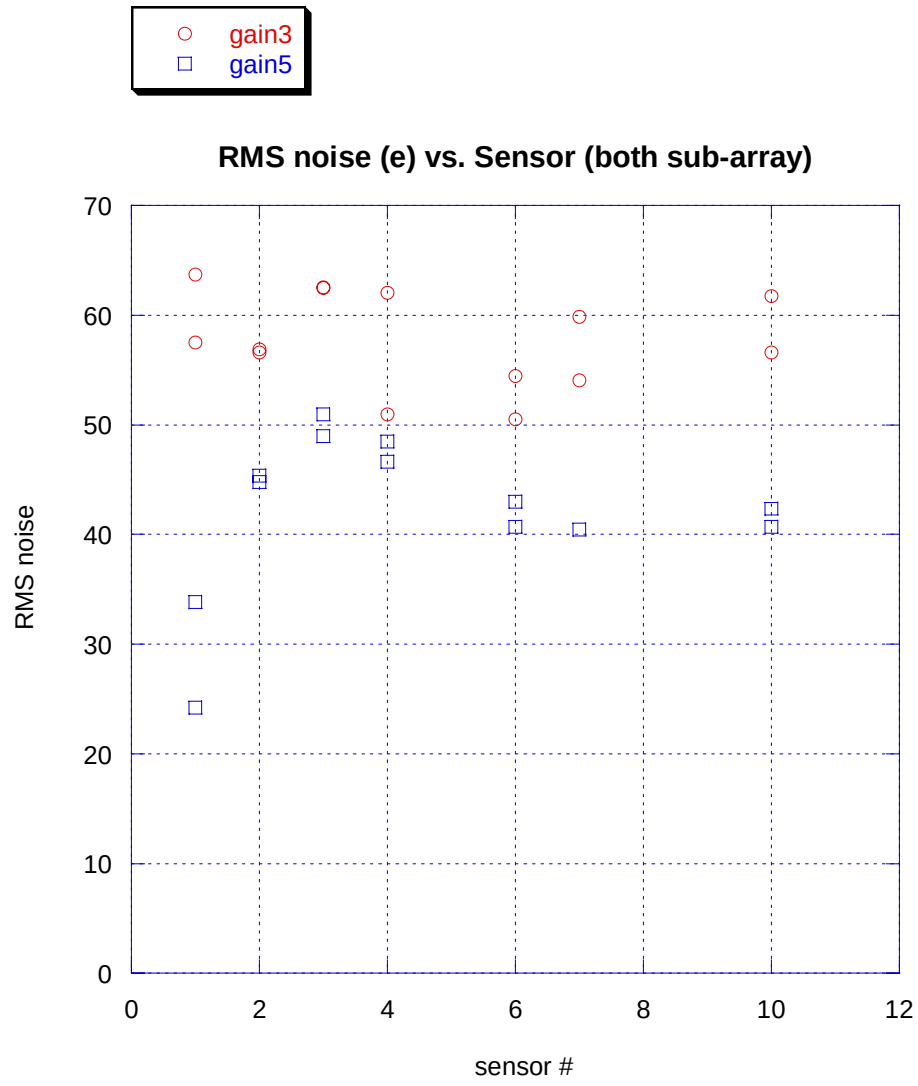
We calibrated three new production Mimostar3 sensors with the 55Fe source and took noise measurements only for the other sensors. The noise statistics shown are for a run 1000 frames for each sensor. Electron to ADC conversions in the noise measurements are taken for the nominal values of gain3 = 15.06 and gain5 = 5.95 for the non-calibrated sensors. Frames are taken in groups of five contiguous frames (speed limitation of the DAQ system) which yields 800 CDS measurements.

The results are shown in the table below;

Mimostar3 (new production)

Test chip #	**Sub-array**	**gain**	**Leakage current (IPHC chip)**	**^{55}Fe peak (ADC)**	**e / ADC**	**RMS Noise (e)**
2 (A4)	0	3	5.4	105	15.58	56.59
2 (A4)	0	5	5.4	280	5.84	44.78
2 (A4)	1	3	5.4	105	15.58	56.89
2 (A4)	1	5	5.4	275	5.95	45.35
7 (C6)	0	3	3	101	16.20	59.83

7 (C6)	0	5	3	275	5.95	40.46
7 (C6)	1	3	3	100	16.36	54.05
7 (C6)	1	5	3	170 ?	9.62 ?	57.38 ?
6 (D3)	0	3	2.4	103	15.88	54.47
6 (D3)	0	5	2.4	286	5.72	40.70
6 (D3)	1	3	2.4	102	15.06	50.51
6 (D3)	1	5	2.4	275	5.95	42.98
1 (A2)	0	3	5.2		nominal	63.7
1 (A2)	0	5	5.2		nominal	33.84
1 (A2)	1	3	5.2		nominal	57.51
1 (A2)	1	5	5.2		nominal	24.22
3 (B2)	0	3	3.6		nominal	62.54
3 (B2)	0	5	3.6		nominal	48.93
3 (B2)	1	3	3.6		nominal	62.48
3 (B2)	1	5	3.6		nominal	50.94
4 (B3)	0	3	3.3		nominal	62.05
4 (B3)	0	5	3.3		nominal	46.61
4 (B3)	1	3	3.3		nominal	50.95
4 (B3)	1	5	3.3		nominal	48.46
10 (E3)	0	3	3.9		nominal	61.76
10 (E3)	0	5	3.9		nominal	42.34
10 (E3)	1	3	3.9		nominal	56.60
10 (E3)	1	5	3.9		nominal	40.69



Additionally, we tested for basic pixel function by taking runs for each sensor with the sensor exposed to light and in dark. The per-pixel raw ADC subtractions showed no dead pixels.

Conclusions with respect to Phase-1 Fabrication

The new fabrication batch of the Mimostar3 sensors from the updated design and run through the AMS foundry process has fixed the dead pixel problem observed in the earlier runs. All sensors that were diced from the wafer and had been previously probe tested at IPHC and found to be functional did function when bonded to testing boards. Sensors from positions C5 and G3 could not complete the noise tests due to the first pixel marker being intermittent. We did not troubleshoot this further. There are several areas of divergence with the measured properties of Mimostar2, they are listed below;

- Signal level for ^{55}Fe peak – The gain = 3 signal level for Mimostar3 for ^{55}Fe is consistently ~ 100 ADC counts. The gain = 3 signal level for the rad-tolerant

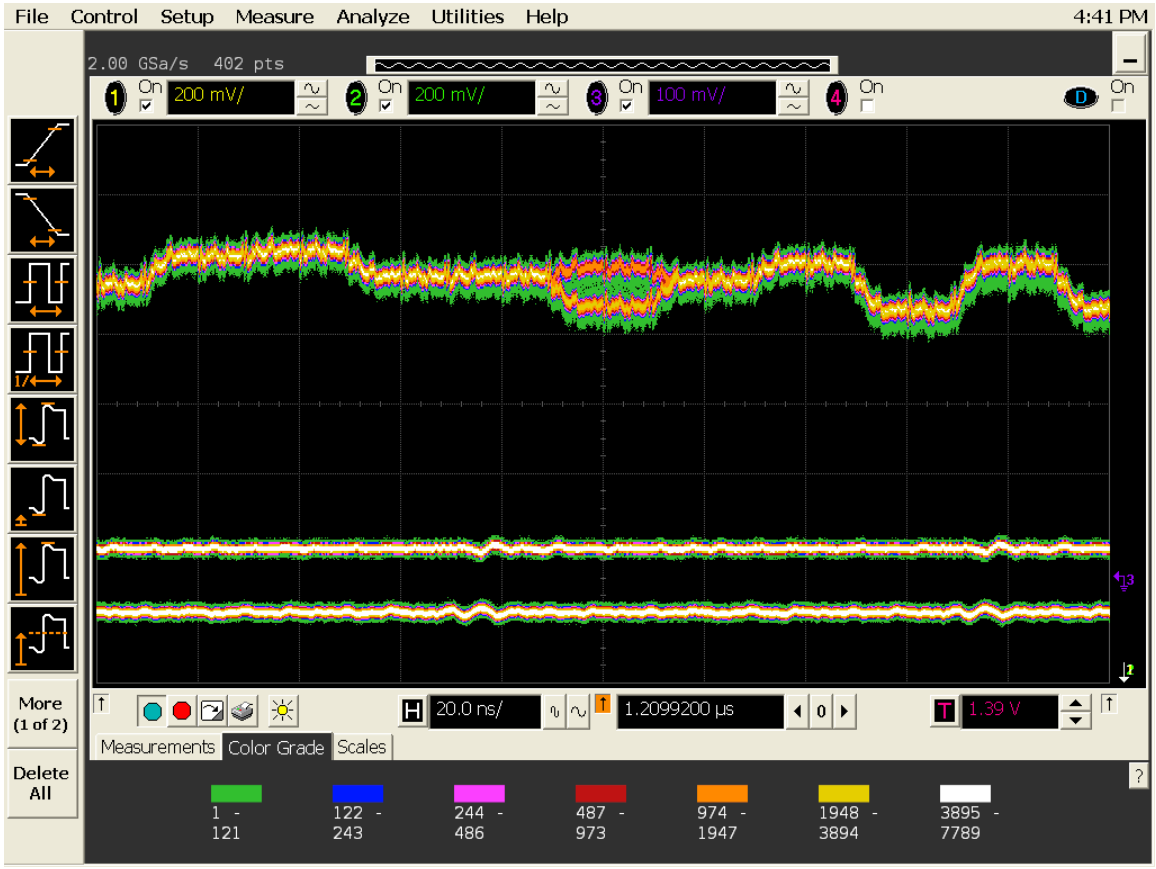
pixel array of Mimostar2 is ~ 212 ADC counts. All data is taken through the same hardware. This is a quite significant difference. What is the cause?

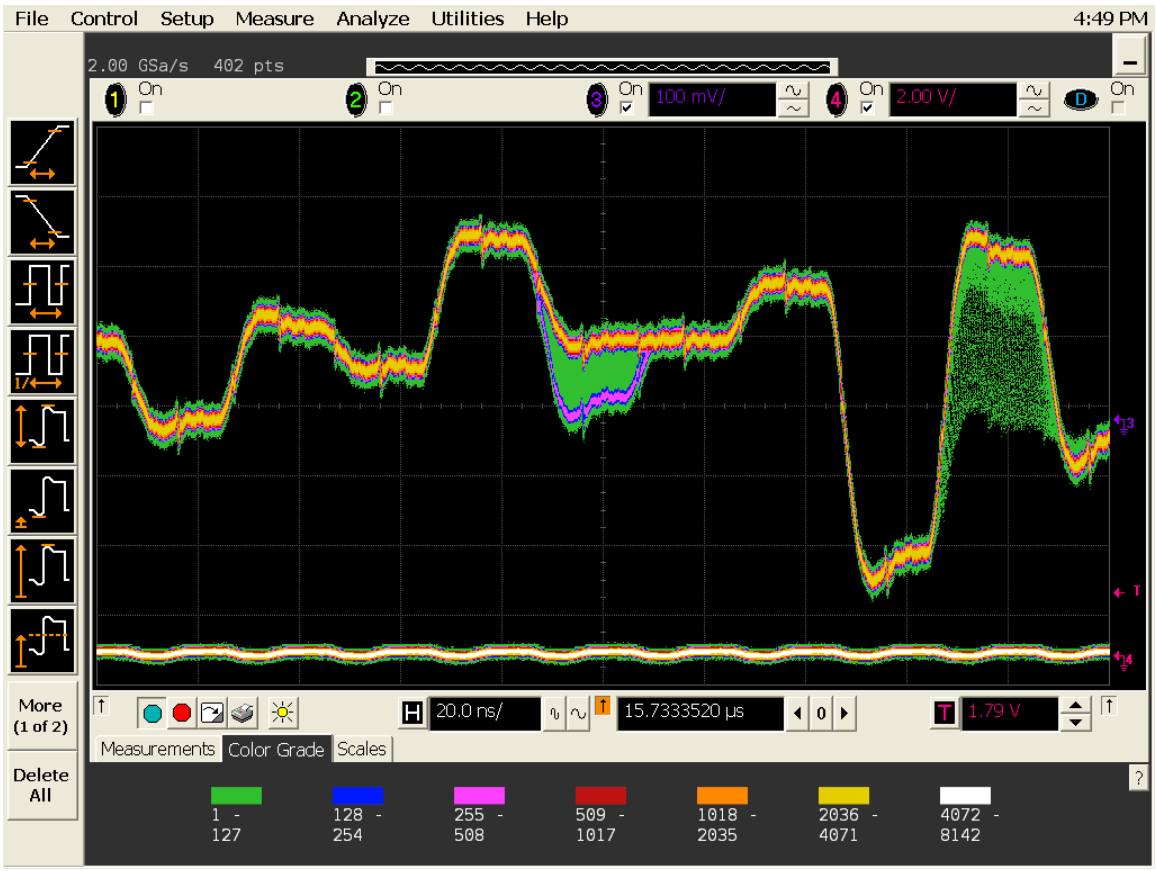
- High noise – The average RMS noise for gain=3 Mimostar3 is ~ 57 electrons. The observed RMS noise for Mimostar2 is ~ 20 e, which is relatively consistent with previous measurements. What is the cause of this high level of noise?
- Discrepancy in JTAG 3/5 gain setting - The ratio of 5/3 is 1.67, the Mimostar2 calibration peak ratio for gain5/gain3 is 1.68, 1.74. The Mimostar3 calibration peak gain5/gain3 ratio is ~ 2.67, 2.62. What has changed in this gain setting between Mimostar2 and Mimostar3?
- Presence of "hot" pixels – More on this is shown below.

These observations should be judged by what relevance they have to the scale-up process from Mimostar2 to Mimostar3 and what overlap that process has with the scale-up process from Mimosa22 to Phase-1. This is a detailed question for the sensor designer. Does the observed behavior of mimostar3 indicate a need for the review of the Mimosa22 scale-up process and what can be done to minimize the impact (if any) of that process of the final operating characteristics of Phase-1?

Additional observations of "hot" pixels

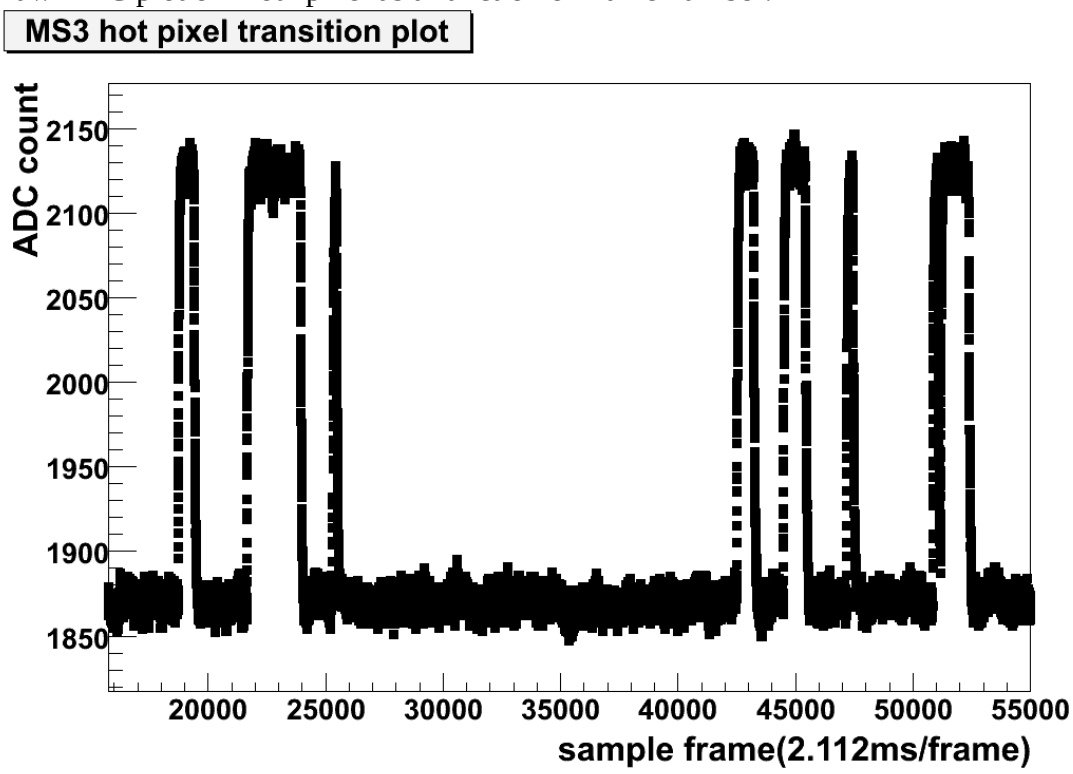
During the testing of the new fabrication batch of Mimostar3 sensors we observed some interesting characteristics. Some significant number of pixels appear to exhibit a bi-nodal state behavior. Some oscilloscope traces in intensity histogram mode of this behavior are shown below.



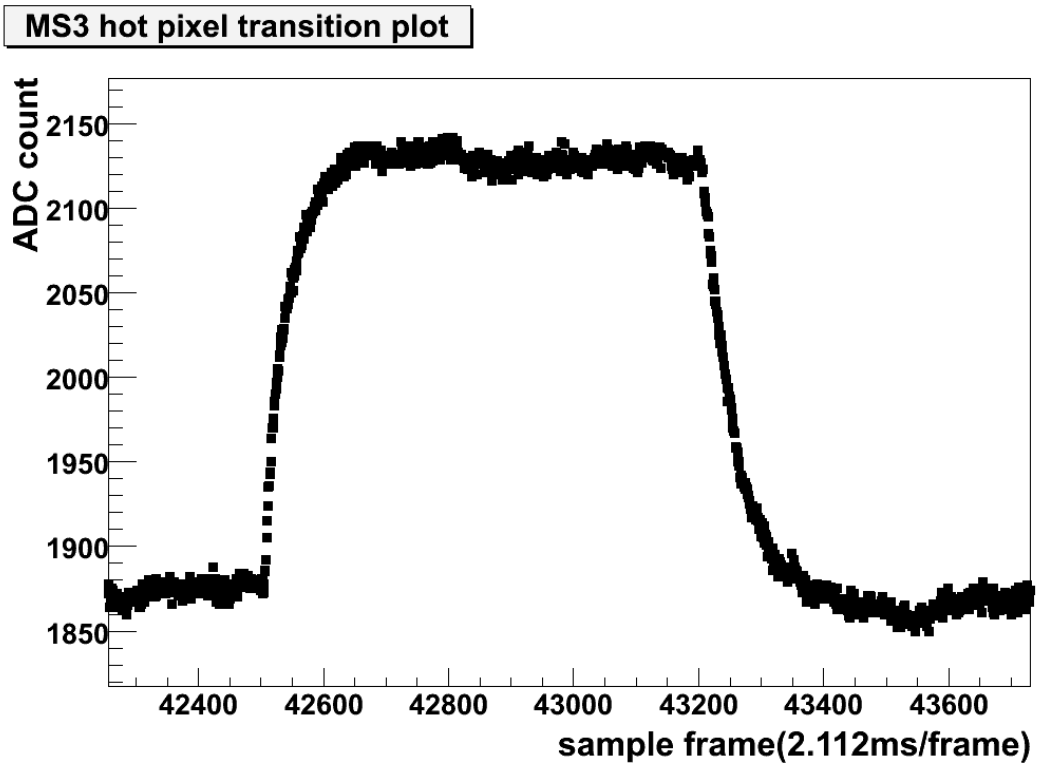


We observe that the states change with a period that probably averages near 1 Hz but is different for all pixels. The states can be from less than 50 mV to more than 250 mV apart and the speed of the transition also varies. Some seem almost instantaneous whilst others seem to take up to 1 second. We are starting quantitative studies now and will report additional progress as it is achieved. This appears to be some form of random telegraph noise. It is possible and perhaps likely that these “hot” pixels do not affect the pixel function as a sensor. If the transition time is of the order of the self biased structure time constant, these transitions will be invisible to CDS. If the transition is fast with respect to a frame time, this will give an average 1 Hz background.
Update – we have measured the transition time for some of these pixels, some plots are shown below;

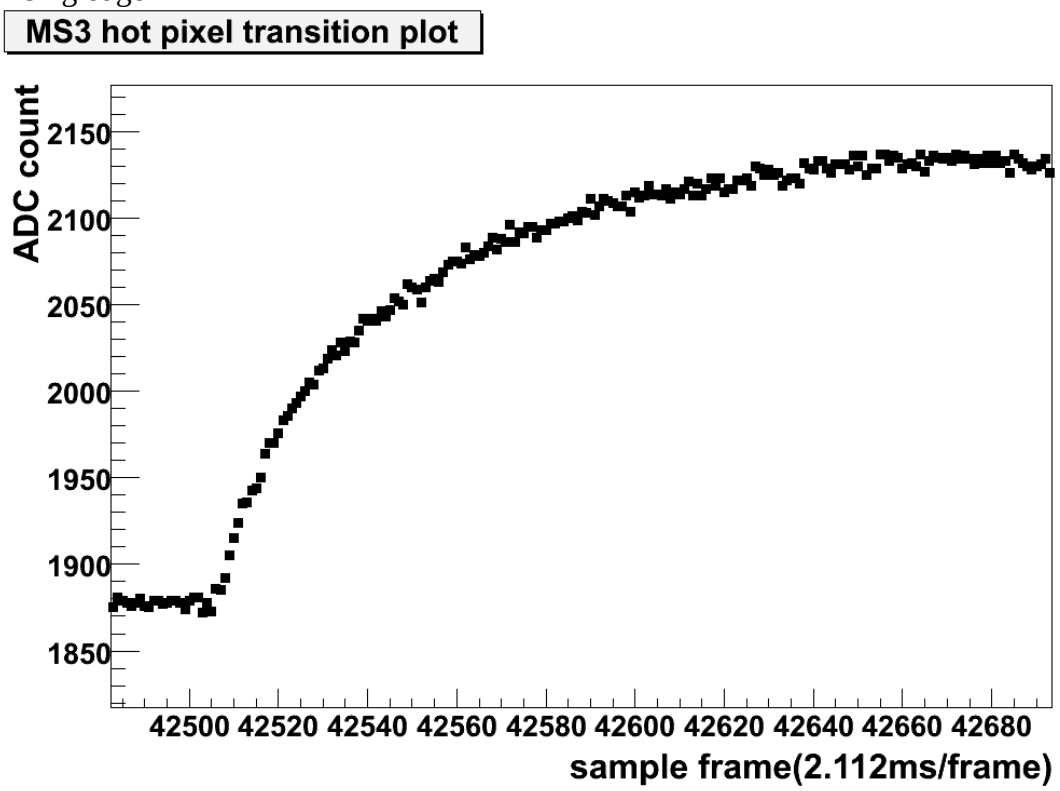
Raw ADC plot of “hot” pixel as a function of frame number.



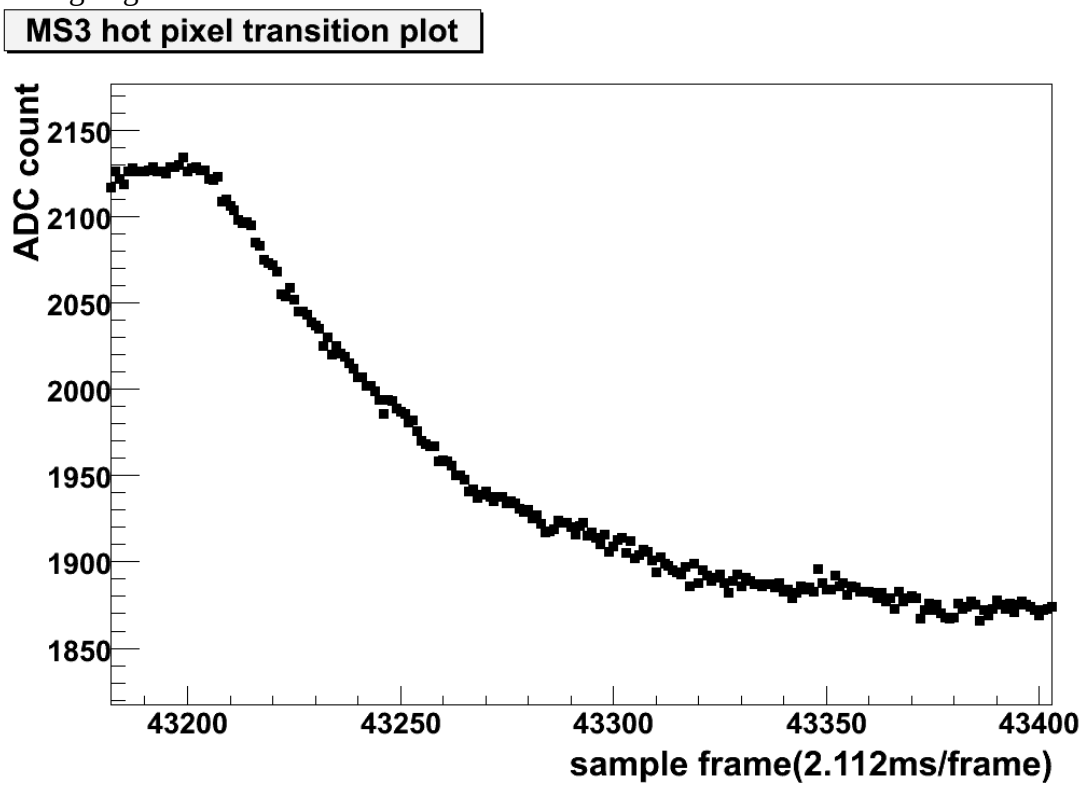
Whole transition



Rising edge



Falling edge



As we can see, the largest transition in frame space is ~ 10 ADC counts. This is visible for Mimostar3 integration times but this may not be the case for shorter integration times, provided the time constant of the transition remains the same.