INGRID Integration Timing Characterization (Software version 3.2)

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Introduction

A discrepancy between the integration time (as reported in the FITS headers of the images) and the real integration time, was found in all INGRID images obtained between May 2000 and January 2001. During this period, version 3.1 of the timing board software was running in the detector controller (SDSU). This *timing error* was characterized and reported to be 0.296s (to be added to the integration time shown in the FITS headers).

The timing board software version changed to 3.2 in March 2001 after the February 2001 optimization work. However, an error still exists in the reported integration time of all INGRID images.

This document reports the timing error associated to the version 3.2 (V3.2) of the INGRID SDSU array controller software and describes some other indirect timing error measurements.

1 Direct measurements

For integrations taken with correlated double sampling readout mode (mndr[1]=1; header parameter INGNR=1), the time between the moment in which the first pixel of the array is readout (just when the pre-read starts)[2] and the moment in which the first pixel of the second readout of the array takes place (the post-read), is the effective integration time.

The effective integration time has been measured for a range of requested exposure times (from 0.6s to 5s) by means of a oscilloscope. We found that the difference between the measured and the requested, and reported, exposure time was constant with time (i.e. it does not depend on the requested exposure time) and equal to:

$$\boxed{(+0.264\pm0.004)\ \mathrm{s}}$$

Through direct measurements of the timing characteristics it is determined that the latency between the first pixel and last pixel read from each quadrant is 0.732s.

[1] mndr = multiple non-destructive readout
[2] after the reset process and the mux flush

2 Indirect tests

Indirect tests were done after March 2001, in order the test the reliability of the reported integration time under version 3.2. These tests and their results are briefly described below.

2.1 On-sky test (C. Benn)

This test was developed by Chris Benn on the first of April. It consisted in pointing the telescope to the Equator and taking exposures with the telescope stopped (i.e. not tracking), so that star images were trails on the array. Assuming that the stars in the Equator drift at 15 arcsec per second, we can calculate the 'real' integration time by measuring the trail lengths in pixels and converting them into arcsecs[3]. Therefore a trail of 63.01 pixels in length on the INGRID array corresponds to a 1 second exposure.

Since the real distances covered by the stars are not equal to the total trail lengths, due to the fact that stars are not imaged as perfect point sources, it was necessary to take this into account by measuring the width of each trail and subtracting it from the total measured length.

The results are shown in Table 1.

The mean value of the differences between the measured and the requested exposure times is 0.249s and the standard deviation is 0.014s. Data has been weighted in calculating the mean value: weights equal to 0.5 for the faint stars and equal to 1 in all other cases.

2.2 Linearity tests (R. Greimel)

Linearity tests were performed in K and Ks. The resulting intensity level across the array (in ADU) as a function of the requested exposure time, was fitted to a second order polynomial. The extrapolation of the fits towards zero intensity gives the timing error (assuming that at exposure time zero, the array should show a zero count level).

The mean value for the timing error obtained from the extrapolation of the linearity tests in K and Ks is (0.275 ± 0.02)s, where the error is the quadratic addition of the timing error obtained with each test.

3 Conclusion

The timing errors measured with the indirect tests are, considering the error bars, consistent with the timing error measured directly with the oscilloscope. Therefore they confirm the directly measured timing error of (0.264 ± 0.004)s.

[3]using the current pixel size of the array, i.e. 0.238"/pix (it was 0.242"/pix before 22nd of March 2001).

Table 1: Column 1: Requested exposure time; column 2: (x,y) position of the beginning of the star trail in the array; column 3: (x,y) position of the end of the star trail on the array; column 4: trail width in pixels; column 5: trail length in pixels; column 7: quadrant of the array in which the trail is placed; column 8: calculated exposure time from the trail length; column 9: comments.

requested time (s)	star trails start position	end position	width (pix)	length (pix)	quadrant*	measured time (s)	comments
5s	(318,425)	(650,424)	1.5	333	2	5.26	faint star
3s	(321,690)	(527,690)	4	207	4,3	3.22	
2s	(624,232)	(770,231)	5	147	2	2.25	
	(419,375)	(561,376)	1.5	143	1,2	2.25	faint star
	(762,906)	(905,906)	2	144	3	2.25	faint star
1.5s	(630,417)	(744,417)	5	115	2	1.75	
	(537,317)	(650,317)	3	114	2	1.76	
	(406,769)	(516,769)	2	111	4,3	1.73	faint star
	(45,331)	(158,331)	3	114	1	1.76	
1.0s	(443,532)	(525,532)	5	83	4,3	1.24	
	(225,932)	(306,933)	3	82	4	1.25	
	(628,657)	(707,658)	1.5	80	3	1.25	faint star
0.6s	(68,931)	(125,930)	4	58	4	0.86	
	(137,480)	(190,480)	2	54	1	0.83	faint star
	(886,190)	(944,189)	4	59	2	0.87	
0.8s	(676,865)	(746,865)	5	70	3	1.05	
	(640,799)	(709,799)	4	70	3	1.05	

* Quadrants are numbered in anti-clock wise, starting from the botton-left quadrant.

3.1 Timing correction

In order to get the real on-sky integration time of the INGRID images obtained with software version 3.2[4] of the timing board of the SDSU controller, the following should be done:

- Check that your INGRID images were obtained with software version 3.2 of the SDSU controller. If that is the case, the header parameter INGSWID should appear as follow:

```
INGSWID = '3.2-3.2-3.1-3.1    ' / Detector Controller Software Identifier
```

- Check the keyword INGRDTIM; it ought to be:

```
INGRDTIM=                 0.600 / Array Read Time (s)
```

- Look for the number of multiple non-destructive readouts performed. (keyword INGNR in the headers).

[4]For software versions prior to 3.2, see the summary in the Appendix at the end of this document.

- If INGNR=1 (double correlated sampling), the case for most science observations, then the integration time reported in the FITS images should be increased by 0.264 s. For example, if the reported integration time is

  ```
  EXPTIM  =                    8 / On-sky Exposure Time (secs)
  ```

  the corrected integration time is 8.264 s.
- If INGNR=n (n>1), the reported integration time must be adjusted as follows:

  EXPTIM+(readout time-0.6s)*n+mux flush time,

  where readout time=0.732s and mux flush time=0.132s.

These corrections do not depend on the number of coaverages performed (keyword INGNC in the FITS headers).

Appendix

For software versions prior to 3.2 (i.e. for observations taken before March 2001), the following corrections should be applied in order to get the real on-sky integration time of the INGRID images:

- Version 3.1 (From 5th May 2000 to 28th February 2001).
  - Check that the images were obtained with software version 3.1 of the SDSU controller. The header parameter INGSWID should appear as follows:

    ```
    INGSWID = '3.1-3.1-3.1-3.1   ' / Detector Controller Software Identifier
    ```

    and the reported readout time should be:

    ```
    INGRDTIM=              0.600 / Array Read Time (s)
    ```

  - Find the number of multiple non–destructive readouts performed (keyword INGNR in the headers).
    * If INGNR=1, the integration time reported in the FITS images ('EXPTIM' in the headers), should be increased by 0.296s.
    * If INGNR=n (n> 1), the reported integration time must be corrected in the following way:
      EXPTIM+0.150*n+0.146,
- Other cases (observations obtained before 4th May 2000)

  The exposure time as recorded in the FITS headers must be increased by 0.146 seconds only, independently of the number of non-destructive readouts (keyword INGNR) performed.