MIT Kavli Institute   Chandra X-Ray Center

MEMORANDUM
February 24, 2015

To: Jonathan McDowell, SDS Group Leader

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Subject: ACIS Dead Area Algorithm and File Specifications

Revision: 1.2.1 February 24, 2015

URL: `http://space.mit.edu/CXC/docs/docs.html#deadarea`

File: `~dph/h3/CXC/ARD/Doc/ACIS_Dead_Area/acis_da_spec-1.2.1.tex`

Cosmic ray interactions with the CCD silicon causes a local interference with X-ray event detection and renders small regions useless for that frame. This cosmic ray flux creates a statistical decrease in exposure time which we need to incorporate into computation of the ACIS response. The affect is referred to as "dead area", though it may more properly be considered "dead time". Since pileup modeling requires exposure time factored from the QE, we must explicitly compute the effect separately from the QE.

Relevant Documents

1. "ACIS Cosmic Ray Induced Dead Area: Part I (Front Illuminated CCDs)" (March 25 2003) presents an analysis of calibration data and derivation of mean dead-area.

   (`http://asc.harvard.edu/acis/memos/ybutt_CR_DEAD_memo1.pdf`)

2. "ACIS Cosmic Ray Induced Dead Area close-out" (August 30, 2004) continues analysis above, and analyzes dead-area vs. $CHIPY$.

   (`http://asc.harvard.edu/acis/memos/brads_cr_dead_memo.ps`)

3. "Factoring the ACIS QE": Section 4 gives a derivation of a dead-area model, and defines the coefficient, kf_c, defining the fractional rate of area loss. The left hand side of equation 10, $\overline{F}_\Omega(\alpha_0)$ is assumed to be the calibration product, which will be tabulated per CCD.

   (`ftp://space.mit.edu/pub/davis/misc/qe-0.3.1.ps`)

4. "ACIS Science Instrument Software User's Guide", section 4.1.1.2, contains a formula for the minimum frame time, required for determining the frame-store contribution to dead area ("`min_time`"):

   (`http://acis.mit.edu/acis/swuserA/swuser_scirun.html#s4_1_1_2`;
   `http://acis.mit.edu/acis/swuserA/swuser.pdf`)

1 Computation of Exposure Time

The dead-area model (Document 3) requires the computation of the frame-store contribution to the exposure time, $\tau_f(y, \alpha)$, also known as the "minimum integration time". The definitive formula for this is given in Document 4, with the interpretation that α refers to all the clocking parameters (for example, overclock pairs, number of CCDs, on-chip summing), and that y refers some particular row rather than the total number of rows.

In addition to the `CHIPY` and readout-mode dependent time, τ_f, there is the imaging-array exposure, τ_i, which is usually set equal to τ_f for efficient observing, but it need not be identical. The total exposure time is thus

$$\tau(y, \alpha) = \tau_f(y, \alpha) + \tau_i \tag{1}$$

An expression for the nominal frame-time is given in the "Proposers Observatory Guide" (POG; `http://cxc.harvard.edu/proposer/POG/html/ACIS.html` section 6.11.3), is approximately equal to the above referenced expression (Document 4) for the nominal case of 256 pixel nodes, no on-chip summing, and 8 over-clock pairs. Figure 1 shows the efficiency factor for a range of parameters. The effects due to starting row and number of active CCDs is small, and probably negligible, amounting to no more than 0.5%.

2 Input Data

2.1 Files and Keywords

Information relevant the frame-time equation comes from the parameter block file, "`pbk0`". The relevant header keywords are:[1]

```
EXTNAME = 'PBK     '              / Table name
HDUNAME = 'PBK     '              / If no EXTNAME
CONTENT = 'PBK     '              / What data product
NAXIS2  =                      6 / number of rows in table
READMODE= 'TIMED   '              / Read mode (for ACIS only)
SUM_2X2 =                      0 / On-chip summing. 0:None; 1:Sum 2x2
STARTROW=                    448 / Index of first row to clock out CCDs
ROWCNT  =                    127 / One less than the number of rows to clock out
OCLKPAIR=                      8 / # of pairs of overclock pixels per output
ORC_MODE=                      0 / Output register clocking mode
EXPTIMEA=                      7 / Primary exposure time in units of 1/10s
EXPTIMEB=                      0 / Secondary exposure time in units of 1/10s
```

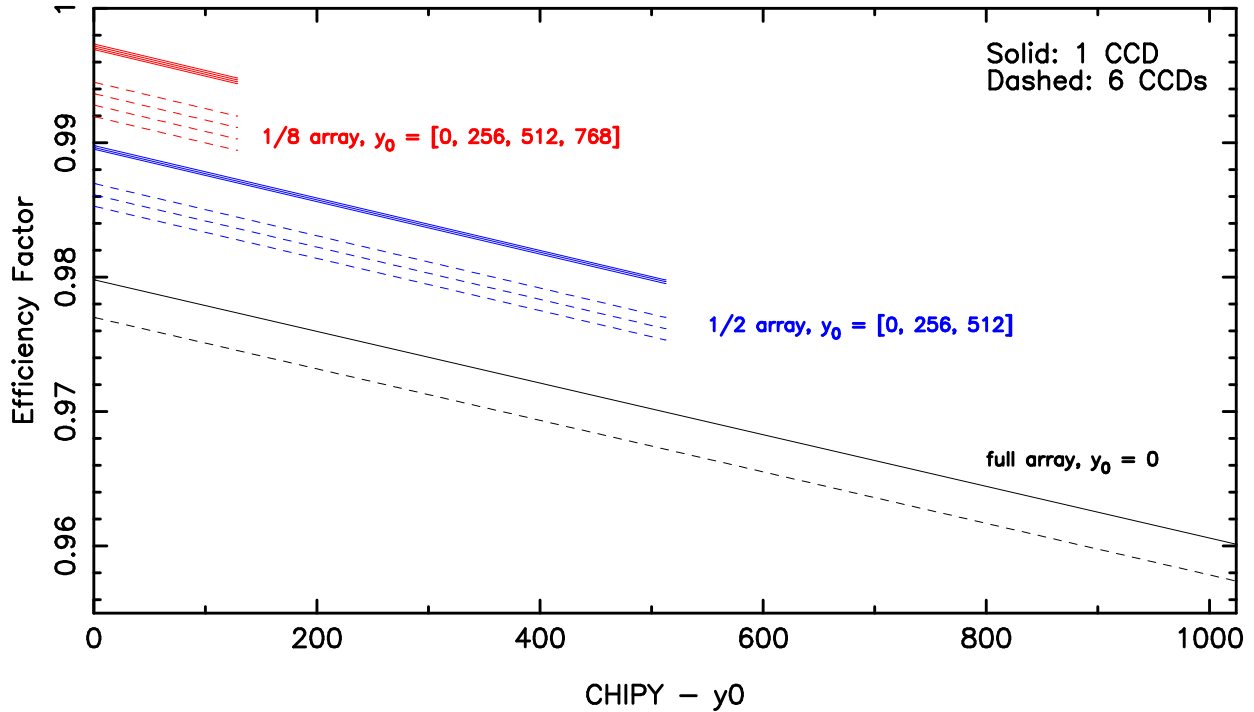[1]Taken as a specific example from `ObsID 5332, acisf206196003N001_pbk0.fits`).

Figure 1: Dead-area efficiency factor for a nominal fractional dead area fraction of 0.036. Solid lines are for a single active CCD, and dashed are for 6. The series of dashed lines show the effect of the starting row, y_0; larger values result in decreased efficiency, due to the slightly increased time being flushed to the readout. The slope of the lines is due to the 2.85 ms read per row from the frame store array.

Notes

1. There can be *two values for* τ_i. Usually one will be zero. But if the mode is interleaved, then each of `EXPTIMEA` and `EXPTIMEB` will be non-zero.

2. The clock-interval (10^{-5} s) is not included in the "`pbk0`" file.

3. `ROWCNT` is not formerly a parameter of the exposure-time for relative y, but it does specify the maximum valid value of y which in turn specifies the minimum frame-time.

4. For CC-mode (`READMODE = 'CONTINUOUS'`), there will be no dependence on y. The relevant frame-time will be $\tau(y = 1024, \alpha_{cc})$

2.2 Calibration Inputs

The required data from Calibration is a table of the mean dead area fraction for each CCD, the area over which it was averaged, and the clocking mode or corresponding `pbk0` file (See Equation 10 of Document 3). The dates of applicability are also required in order to look-up the proper table for any given observation. The computation of the dead-area coefficient from the calibration information is not specified here.

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2.3 Dependencies or Restrictions

The only time-dependence supported is that of the epoch of observation. That is, the CALDB will be queried for the most recent file prior to the date of observation. While it is possible for the dead area fraction to depend upon local conditions (such as background rate), it is not expected that it can be calibrated on fine intervals.

3 Specification of Analysis Reference Data File

The ACIS dead-area fraction is given by Equation 9 of Document 3. The parameter derived from the calibration input (see above, Section 2.2) is the effective rate of fractional area loss, kf_c. This term is known to be different for front- and back-illuminated CCDs. For completeness, it will be tabulated for each CCD, though there may in practice be only two unique values.

3.1 File Names

The `CALDB` type for the ACIS dead area is `dead_area`. File names will be of the forms:

```
acisD<yyyy-mm-dd>dead_areaN0001.fits
```

3.2 File Structure

The ACIS dead-area coefficients, kf_c, will be stored in a FITS binary table, one row, one column binary table extension for each CCD. The file will conform to CXC standards and have the mandatory FITS structural and CXC informational header keywords. The format was chosen to be extensible under some plausible changes. For example, if the calibration were at some point generalized into an image in chip coordinates, then the image and associated world coordinate system would could be easily adapted into the same one CCD per extension table without large changes to exisiting interfaces.

3.2.1 HDU Components

The following table describes the file structure by Header-Data Unit number, type, extension name, content, and HDU classes. An asterisk (*) denotes the principal HDU. All extensions have the EXTNAME, AXAF_DEAD_AREA.

HDU	HDU Type	HDUNAME	CONTENT	HDUCLASS	Description
0	PRIMARY	N/A	N/A	N/A	NULL
1 (*)	BINTABLE	AXAF_DEAD_AREA0	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
2	BINTABLE	AXAF_DEAD_AREA1	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
3	BINTABLE	AXAF_DEAD_AREA2	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
4	BINTABLE	AXAF_DEAD_AREA3	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
5	BINTABLE	AXAF_DEAD_AREA4	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
6	BINTABLE	AXAF_DEAD_AREA5	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
7	BINTABLE	AXAF_DEAD_AREA6	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
8	BINTABLE	AXAF_DEAD_AREA7	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
9	BINTABLE	AXAF_DEAD_AREA8	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient
10	BINTABLE	AXAF_DEAD_AREA9	CDB_ACIS_DEAD_AREA	DEAD_AREA	Dead area coefficient

3.2.2 Columns and Coordinate Systems

For the current (February 24, 2015) calibration, only one row and one column are required to define the dead area scaling for each CCD.

TTYPE	TUNIT	TFORM	TLMIN	TLMAX	Comment
DEAD_AREA_COEF	1/s	1E	0.0	n/a	dead area coefficient

3.2.3 Special Header Keywords

The following are the additional informational keywords required per extension which are particular to the ACIS dead area. In the following, n is to be replaced by the CCD_ID value for that extension.

```
EXTNAME =    'AXAF_DEAD_AREA'
EXTVER =     n
CONTENT =    'CDB_ACIS_DEAD_AREA'
HDUCLAS =    'DEAD_AREA'
INSTRUM =    'ACIS'
DETNAM =     'ACIS-n'
DATACLAS =   'CALIBRATION'
TITLE =      'ACIS Dead area coefficients'
```

3.2.4 CALDB Keywords

The required CALDB keywords are as follows:
```
CCLS0001=   'BCF'
CDTP0001=   'DATA'
CCNM0001=   'DEAD_AREA'
CBD10001=   'CCD_ID(0-9)'
CVSD0001=   yyyy-mm-ddThh:mm:ss
CVST0001=   hh:mm:ss
CDES0001=   'ACIS Dead Area Coefficient'
```

3.3 Size and File Number Estimates

There will be one file per epoch of calibration. Each file will have 11 headers (NULL primary and principal HDU). The total file size is expected to about 100 kB.