**MIT**

**Center for Space Research** **Chandra X-Ray Center**

**MEMORANDUM**

September 9, 2002

| | |
|---|---|
| **To:** | Martin Elvis, SDS Group Leader |
| **From:** | Glenn Allen, SDS |
| **Subject:** | The computation of FLTGRADE, GRADE, and PHA |
| **Revision:** | 1.3b |
| **URL:** | http://space.mit.edu/CXC/docs/docs.html#grades |
| **File:** | /nfs/cxc/h2/gea/sds/docs/memos/memo_fltgrade_grade_pha_1.3b.tex |

This memo describes the computation of the values of the columns FLTGRADE, GRADE, and PHA for Level 1 TIMED FAINT, TIMED VFAINT, and CONTINUOUS CC33_FAINT mode ACIS event data. These computations are based on the distribution of charge in the central 3 pixel by 3 pixel "event island" of an event. If the CTI adjustment has not been performed, the distribution of charge is quantified in the column PHAS. If the adjustment has been performed, use the column PHAS_ADJ instead of PHAS. Since the algorithms used for CTI-adjusted data differ somewhat from the algorithms used for unadjusted data, the differences are described. This memo supercedes the document entitled "CXC implementation of ACIS event grading schemes (V1.1)" (see http://space.mit.edu/CXC/docs/grades.ps.gz).

## 1 Indexing the PHAS Array

For TIMED VFAINT and CONTINUOUS CC33_FAINT mode observations, the relative CHIPX and CHIPY coordinates of each pixel of an event island are shown in Figure 1. The coordinates of the central pixel of the event island are reported as the location of the event on the detector. Figure 1 also shows the appropriate one ($i$) and two ($j, k$) index values for each pixel of the event island.

## 2 FLTGRADE

The value of the FLTGRADE of an event is a numerical representation of the distribution of charge in the event island. The value is given by

$$\mathrm{FLTGRADE} = \sum_{i=0}^{8} \alpha_i f_i, \tag{1}$$

where $\alpha_i = 1$ if the pixel is valid, $\alpha_i = 0$ if the pixel is not valid, and the value of $f_i$ is different for each pixel in the event island (Fig. 2). The range of possible values for FLTGRADE is 0–255 inclusive.

A pixel is considered valid for the computation of FLTGRADE (i.e. $\alpha_i = 1$) if all of the following set of criteria are satisfied.

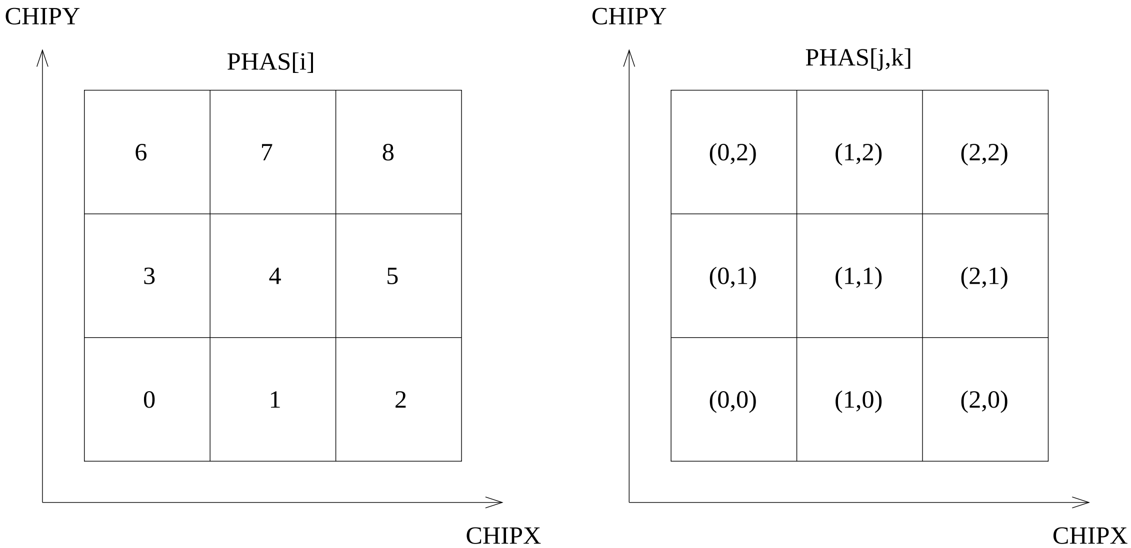


Figure 1: The relative CHIPX and CHIPY coordinates of the nine elements of a 3 pixel by 3 pixel ACIS event island (i.e. the nine elements of PHAS or PHAS_ADJ for TIMED FAINT and CONTINUOUS CC33_FAINT mode data). The figure on the left-hand (right-hand) side is appropriate if one (two) index is used.

1. The amount of charge in the pixel must be greater than or equal to the split threshold $s$. (The default value of the split threshold $s = 13$ adu.) If the CTI adjustment is not performed, then this condition is satisfied if
$$\mathrm{PHAS}[i] \geq s. \tag{2}$$
If the CTI adjustment is performed, then this condition is satisfied if
$$\mathrm{PHAS\_ADJ}[i] \geq s. \tag{3}$$

2. If the CTI adjustment is not performed, then the amount of charge in the pixel should not exceed the maximum value that can be obtained using a twelve-bit analog-to-digital converter:
$$\mathrm{PHAS}[i] \leq 4095. \tag{4}$$
If the CTI adjustment is performed, the amount of charge in a pixel is set to 4095 adu if $\mathrm{PHAS\_ADJ}[i] > 4095$ for the pixel. In this case, Equation 4 is satisfied by design.

3. If the CTI adjustment is not performed, the amount of charge in the outer eight pixels of the 3 pixel by 3 pixel event island must not exceed the amount of charge in the central pixel of the event island. For some of the pixels, the appropriate inequality is "$\leq$." For others, it is "$<$" (Fig 3). If the index number $i$ for the pixel is in the range 0–3 (see the left-hand side of Fig. 1), then this condition is satisfied if
$$\mathrm{PHAS}[i] \leq p_{\mathrm{c}}, \tag{5}$$
where $p_{\mathrm{c}}$ (= PHAS[4]) is the amount of charge in the central pixel. If the index number for the pixel is in the range 5–8, then this condition is satisfied if
$$\mathrm{PHAS}[i] < p_{\mathrm{c}}. \tag{6}$$
If the CTI adjustment is performed, the outer eight pixels of the event island may have more charge than the central pixel.

In summary, if the CTI adjustment is not performed and Equations 2, 4, and 5 (or 6) are satisfied for a given pixel, the value of $\alpha_i = 1$ for the pixel and it is included in the computation of the value of FLTGRADE (see Equation 1). If one of more of these equations is not satisfied, the pixel is not valid and $\alpha_i = 0$. If the CTI adjustment is performed, $\alpha_i = 1$ if and only if Equation 3 is satisfied. If Equation 3 is not satisfied, then $\alpha_i = 0$ for the pixel.

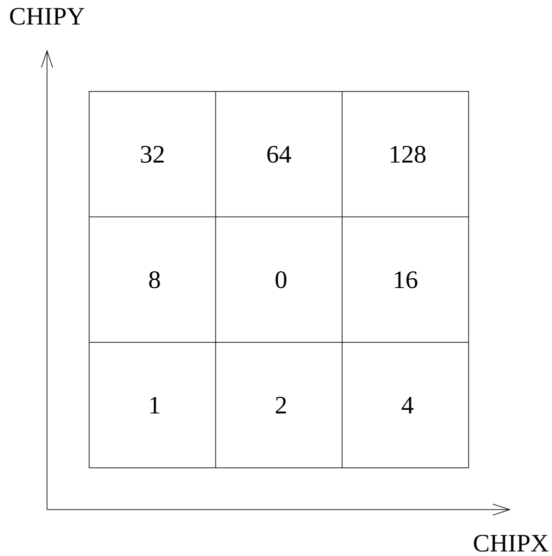


Figure 2: The values of $f_i$ (Eqn. 1) for each of the nine pixels of an event island.

# 3 GRADE

The value of the GRADE of an event is based on the value of the FLTGRADE of an event. The range of possible values for GRADE is 0–7 inclusive. The scheme used to determine the value of the GRADE of an ACIS event is identical to the scheme used to assign the values of GRADE to *ASCA* SIS events. To date, only one scheme has been used for TIMED FAINT, TIMED VFAINT, and CONTINUOUS CC33_FAINT mode observations (Table 1).

# 4 PHA

The value of the PHA of an event is an estimate of the total amount of charge in a 3 pixel by 3 pixel event island. If the CTI adjustment is not performed, the value is given by

$$\mathrm{PHA} = \sum_{i=0}^{8} c'_i \mathrm{PHAS}[i], \tag{7}$$

where $c'_i = 1$ if the pixel is valid and $c'_i = 0$ if the pixel is not valid. If the CTI adjustment is performed, the value is given by

$$\mathrm{PHA} = \sum_{i=0}^{8} c'_i \mathrm{PHAS\_ADJ}[i]. \tag{8}$$

A pixel is considered valid for the computation of FLTGRADE if all of the following set of criteria are satisfied.

1. The amount of charge in a pixel must be greater than or equal to the split threshold $s$. If the CTI adjustment is not performed, then

$$c'_i = 1 \quad \text{if} \quad \mathrm{PHAS}[i] \geq s \text{ and} \tag{9}$$
$$c'_i = 0 \quad \text{if} \quad \mathrm{PHAS}[i] < s. \tag{10}$$

   If the CTI adjustment is performed, then

$$c'_i = 1 \quad \text{if} \quad \mathrm{PHAS\_ADJ}[i] \geq s \text{ and} \tag{11}$$
$$c'_i = 0 \quad \text{if} \quad \mathrm{PHAS\_ADJ}[i] < s. \tag{12}$$

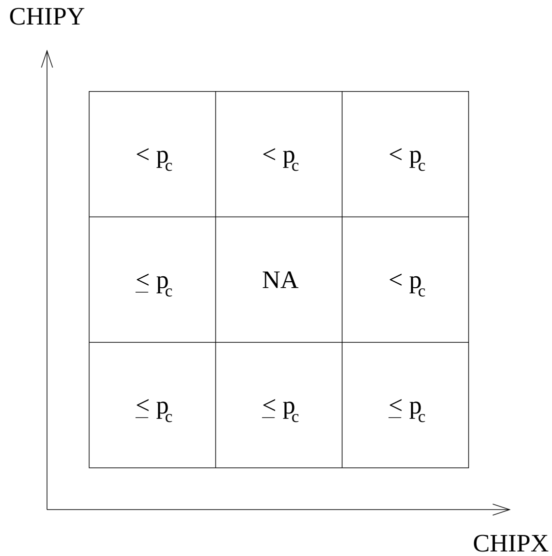


Figure 3: The inequality to be used when comparing the amount of charge in the outer eight pixels of an event island to the amount of charge in the central pixel ($p_c$) of the island (Eqns. 5 and 6).

2. If the CTI adjustment is not performed, the amount of charge in the outer eight pixels of the 3 pixel by 3 pixel event island must not exceed the amount of charge in the central pixel of the event island. For some of the pixels, the appropriate inequality is "$\leq$." For others, it is "$<$" (Fig 3). If the index number for a pixel ($i$ in the left-hand side of Fig. 1) is in the range 0–3, then

$$c'_i = 1 \quad \text{if} \quad \text{PHAS}[i] \leq p_c \text{ and} \tag{13}$$
$$c'_i = 0 \quad \text{if} \quad \text{PHAS}[i] > p_c, \tag{14}$$

   where $p_c = \text{PHAS}[4]$ is the amount of charge in the central pixel. If the index number for a pixel is in the range 5–8, then

$$c'_i = 1 \quad \text{if} \quad \text{PHAS}[i] < p_c \text{ and} \tag{15}$$
$$c'_i = 0 \quad \text{if} \quad \text{PHAS}[i] \geq p_c. \tag{16}$$

   If the CTI adjustment is performed, the outer eight pixels of the 3 pixel by 3 pixel event island may have more charge than the central pixel of the event island.

3. One or more of the corner pixels of a 3 pixel by 3 pixel event island is included in the computation of PHA if the pixel satisfies the appropriate set of criteria. There are four possible sets of criteria. The set of criteria used during processing can be determined from the value of the keyword CORNERS in the header of the event data file. The range of possible values for corners is from $-1$ to $+2$ inclusive. The default value is 2.

   - If CORNERS $= -1$, none of the corner pixels is included in the computation of PHA.
   - If CORNERS $= 0$, all of the corner pixels may be included.
   - If CORNERS $= 1$, a corner pixel may be included in the computation of PHA if one or both of the adjacent outer eight pixels satisfies Equations 9 and 13 (if the CTI adjustment is not applied) or Equation 11 (if the CTI adjustment is applied). This set of criteria is displayed or each of the corner pixels in Figure 4.
   - If CORNERS $= 2$, a corner pixel may be included in the computation of PHA if both of the adjacent outer eight pixels satisfy Equations 9 and 13 (if the CTI adjustment is not applied) or Equation 11 (if the CTI adjustment is applied). This set of criteria is displayed for each of the corner pixels in Figure 5. Furthermore, the value of GRADE for the event must be 6 (instead of 7).

| GRADE | FLTGRADE |
|---|---|
| 0 | 0 |
| 1 | 1, 4, 5, 32, 33, 36, 37, 128, 129, 132, 133, 160, 161, 164, 165 |
| 2 | 2, 34, 64, 65, 68, 69, 130, 162 |
| 3 | 8, 12, 136, 140 |
| 4 | 16, 17, 48, 49 |
| 5 | 3, 6, 9, 13, 20, 21, 35, 38, 40, 44, 52, 53, 96, 97, 100, 101, 131, 134, 137, 141, 144, 145, 163, 166, 168, 172, 176, 177, 192, 193, 196, 197 |
| 6 | 10, 11, 18, 22, 50, 54, 72, 76, 80, 81, 104, 108, 138, 139, 208, 209 |
| 7 | 7, 14, 15, 19, 23, 24, 25, 26, 27, 28, 29, 30, 31, 39, 41, 42, 43, 45, 46, 47, 51, 55, 56, 57, 58, 59, 60, 61, 62, 63, 66, 67, 70, 71, 73, 74, 75, 77, 78, 79, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 98, 99, 102, 103, 105, 106, 107, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 135, 142, 143, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 167, 169, 170, 171, 173, 174, 175, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 194, 195, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255 |

Table 1: The mapping of FLTGRADE to GRADE.

In summary, if the CTI adjustment is not performed and Equations 9 and 13 or 15 are satisfied and the appropriate set of criteria for the corner pixels is satisfied for a given pixel, the value of $c_i' = 1$ for the pixel in Equation 7. If Equation 10 or 14 or 16 hold or the appropriate set of criteria for the corner pixels are not satisfied, then $c_i' = 0$ for the pixel. If the CTI adjustment is performed, $c_i' = 1$ for a pixel in Equation 8 if and only if Equation 11 is true and the appropriate set of criteria for the corner pixels is satisfied. If Equation 12 applies or the appropriate set of criteria for the corner pixels are not satisfied, then $c_i' = 0$ for the pixel.

## 4.1 Default Value of CORNERS

The default value of CORNERS used for standard ACIS pipeline processing has been two. The corresponding set of rules to compute PHA is allegedly the same as the set of rules used to compute PHA for *ASCA* SIS data. However, if a user reruns acis_process_events and recomputes the values of the GRADE of the events, the default value of CORNERS is one. In this case, the corresponding set of rules used to compute PHA is the same as the set of rules used to compute PHA onboard for graded mode observations. Using CORNERS = 1 will ensure that the calibration of the nongraded modes applies to the graded modes as well. However, this issue may be mute in the sense that the events whose PHA values differ if CORNERS = 2 instead of 1 are events whose GRADEs are either 5 or 7.

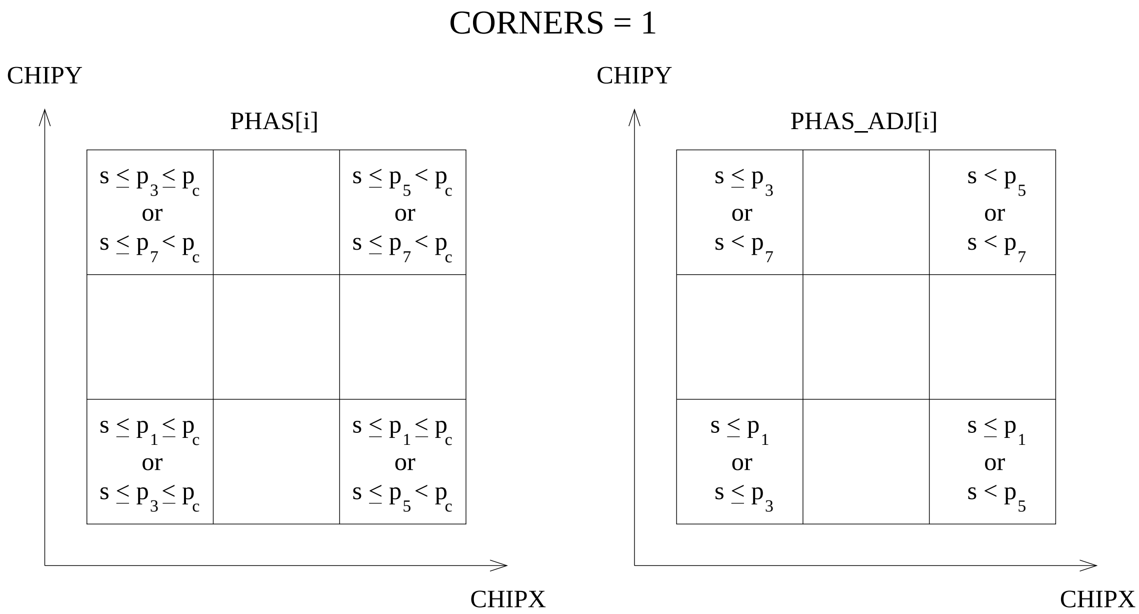


Figure 4: If CORNERS = 1, a corner pixel may be included in the computation of PHA if it satisfies the criteria displayed in this figure. The left-hand figure is appropriate if the CTI adjustment is not applied. Here, $p_i$ = PHAS[$i$]. The right-hand figure is appropriate if the CTI adjustment is applied. In this case, $p_i$ = PHAS_ADJ[$i$]. Note that the inequalities vary from one corner pixel to the next.

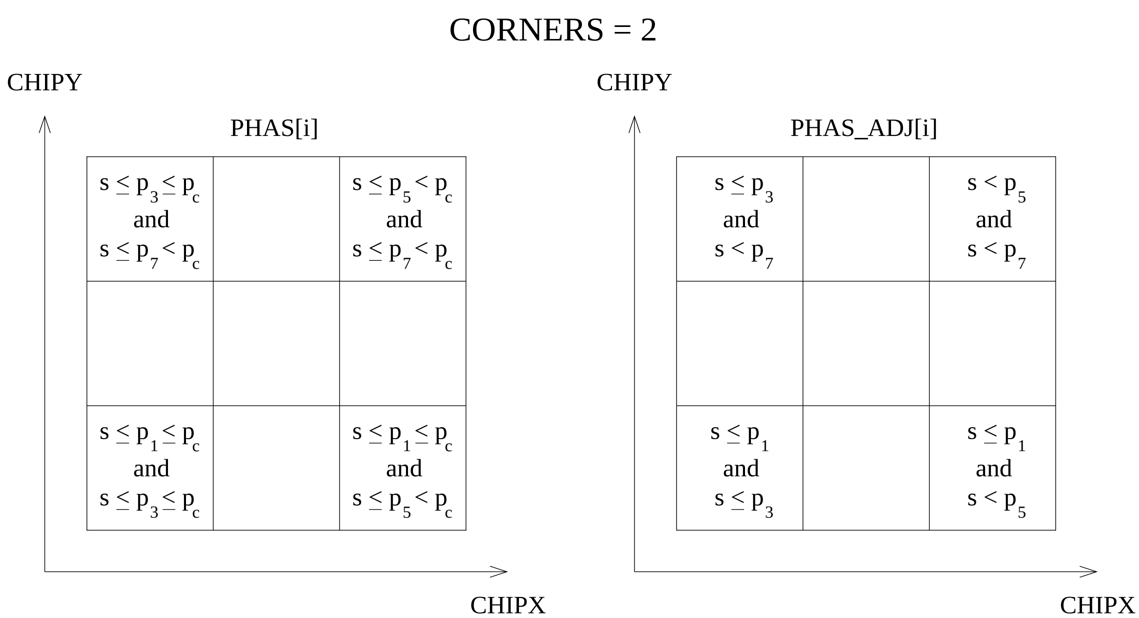


Figure 5: If CORNERS = 2, a corner pixel may be included in the computation of PHA if it satisfies the criteria displayed in this figure. The left-hand figure is appropriate if the CTI adjustment is not applied. Here, $p_i$ = PHAS[$i$]. The right-hand figure is appropriate if the CTI adjustment is applied. In this case, $p_i$ = PHAS_ADJ[$i$]. Note that the inequalities vary from one pixel to the next.