August 1, 2015 Fran Bagenal

Error Values for Each Measurement

From XFULL fortran subroutine within MJSANL we find…

```
C ********************************************************************
C *                                                                  *
C *      ***  STATISTICAL WEIGHTS FOR ERROR ANALYSIS ***             *
C *                                                                  *
C *   THE THERMAL NOISE (IN FEMTOAMPS) IS CNOISE WHERE               *
C *       CNOISE=FAC(ICLK)*SIGNOI                                    *
C *       SIGNOI=35.0 FEMTOAMPS                                      *
C *       FAC(ICLK)=SQRT(CLOCK(3)/CLOCK(ICLK))                       *
C *       CLOCK(ICLK) IS THE INTEGRATION TIME IN SECONDS             *
C *                                                                  *
C *         ICLK      CLOCK       FAC                 *
C *           1         0.03          5.6                 *
C *           2         0.21          2.1                 *
C *           3         0.93          1.0                 *
C *                                                                  *
C *   FOR GS-3 ICLK=2 AND CNOISE=73.5 FEMTOAMPS                      *
C *   THE DIGITIZATION ERROR IS SQRT(FNOIS)*RCURR IN FEMTOAMPS WHERE  *
C *       FNOIS=(10**1/64-1)**2/12 = 1.118E-4 IS THE APPROPRIATE FACTOR
C *                                                                  *
C ********************************************************************

C
C    WEIGHT ONLY INCLUDES THE THERMAL NOISE AND IS THE SAME
C        FOR ALL MEASURED CURRENTS
C
   WEIGHT=1./(CNOISE*CNOISE)
C
C    WT2 INCLUDES BOTH THERMAL NOISE AND DIGITIZATION ERROR
C
   WT2=1./(CNOISE*CNOISE+FNOIS*RCURR*RCURR)
```

It's this second version that is preferable.

So – we have
CNOISE = FAC * 35.0 fAMP
FNOIS=(10**1/64-1)**2/12 = 1.118E-4
Digitization error = SQRT(FNOIS)* RCURR
The net "weight" of the fit = 1/ (Error)**2
Where
Error = SQRT(CNOISE*CNOISE + FNOIS*RCURR*RCURR) – this should be in FemptoAmps.

At this point the only unknowns are:
(1) RCURR – that's the current measured in a particular channel – in fAmp – which should be

read in as an integer for each time-step for each cup for each channel - and converted to fAmp.

(2) What's ICLK so that we know what FAC should be?

Each measurement header has the following…. Example from Voyager 1 electron mode (E1)

1979 64 0 0 31 404 3 16 2 111 1 3 6F6F0000
where the various things in that line stand for
JTB(6),JTLMOD,jne,JCLK,kstat,ipls,ityp,lstat

JTB(6) = integer time
Year Day Hour Min Sec Msec

jtlmod = 3 (E1)
jne = 16 (number of channels)
Jclk = ICLK = 2
kstat = 111
ipls = 1
ityp =3
lstat = 6F6F0000

jclk refers to the integration time of the measurement, not the sampling time, jclk of iclk = 2 means at jupiter we were in the the 210 ms integration time (see attached table for the three integration times for the three possible values of jclk)

Capacitance (ICAP)	Gain (IGAN)	Integration Time (JCLK)	Threshold
0.15 (0)	2 (0)	0.03 (1)	930
1.15 (1)	2 (0)	0.03 (1)	7130.00
0.15 (0)	20 (1)	0.03 (1)	93.00
1.15 (1)	20 (1)	0.03 (1)	713.00
0.15 (0)	2 (0)	0.21 (2)	132.86
1.15 (1)	2 (0)	0.21 (2)	1018.57
0.15 (0)	20 (1)	0.21 (2)	13.29
1.15 (1)	20 (1)	0.21 (2)	101.86
0.15 (0)	2 (0)	0.93 (3)	30.00
1.15 (1)	2 (0)	0.93 (3)	230.00
0.15 (0)	20 (1)	0.93 (3)	3.00
1.15 (1)	20 (1)	0.93 (3)	23.00

Table 3-5: Thresholds for Gains, Capacitances, and Integration Times

This table is from document from John Belcher posted here: http://lasp.colorado.edu/home/mop/files/2015/04/VoyagerDoc_2015.pdf

Worked example – close to our favorite spectrum Fred 1979 64 1016

Here's the original input file. The data numbers (integers to 256) are converted to femptoAmps (using kntcur) that becomes input to all the plotting and fitting routines.

```
01979  64 1010:36.448       2  3D3D   0       2.1       0.0       0.0 15064  1  «,`Û   1      537395510             0
    1   1  16     219  255  255  255  255  255  242  222  198  179  142    0    0    0    0    0

    2  17  32     237  236  234  231  224  211  198  193  192  192  192  192  192  192  192  192

    3  33  48     148  146  142  136  128  128  128  128  128  128  128  128  128  128  128  128

    4  49  64     156  157  159  162  162  152  126  115   50    0    0    0    0    0    0    0

01979  64 1010:55.409       2  8D8D   0       2.1       0.0       0.0 15066  4  «,`Û   1      537395510             0
    4   1  16     154  155  154  152  153  157  160  162  164  166  167  169  175  182  188  190

01979  64 1011:11.  9       2  DDDD   0       2.1       0.0       0.0 15067  2  «,`Û  57      537395510             0
    1   1 128      -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2  115  111  108  104   98   92   86   84
                   81   80   80   79   77   74   71   68   65   62   60   38   45   48   42   37
                   24   26   23   17   27   11    5    0    0    0    0    0    0    0    0    0
                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
    2 129 256      -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2  192  192  192  192  192  192  192  192  192
                  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192
                  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192
                  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192  192
    3 257 384      -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2  128  128  128  128  128  128  128  128
                  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128
                  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128
                  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128
                  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128  128
    4 385 512      -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2   -2
                   -2   -2   -2   -2   -2   -2   -2   -2    8    3    0    8    0    0    0    0
                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
                    3    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
                    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0    0
01979  64 1011:43.409       2  5D5D   0       2.1       0.0       0.0 15068  3  «,`Û   1      537395510             0
    4   1  16     150  135  130  130  130  130  131  132  132  134  135  136  137  138  139  141
```

But we can use this original file to find that **ICLK=2 for these data at Jupiter.**
So…
FAC = 0.21
CNOISE = FAC * 35.0 fAMP = 7.35 fAamp
$CNOISE^2$ = 54.0 $fAmp^2$
Using the measured current RCURR (in fA) then
Error = SQRT(54.0 + 1.118E-4 x RCURR*RCURR) – this should be in FemptoAmps.

For fitting, the WEIGHT that is used should be $1/Error^2$