HIRDLS TC-OXF-72

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SIGNAL CHANNEL DYNAMIC RANGE, GAIN SETTINGS and A to D CONVERSION

Introduction

The IRD gives figures for the expected RMS noise level (NEN), the maximum expected radiance input to each channel and a minimum required [linear] dynamic range margin of 25%. Based on these data one would conclude that the maximum s/n(rms) ratio (channel 8) is around 34,000, that the signal channel (in this case) needs a dynamic range linear up to at least 43,000 x rms noise. Further, following the approach described in TC-NCA-18 [WGM], digitising to 16 bits appears adequate.

The above synopsis does not address two important issues, which are the subject of this TC. One concerns the magnitude of test input signals during the pre-launch phase, i.e during radiometric calibration, IFOV mapping, etc. The other is the question of how to choose the optimum gain setting for each channel.

Test signal magnitudes and dynamic range

For certain test conditions, especially when high-temperature sources are being used, it is virtually impossible to avoid subjecting some channels to input signal levels far in excess of the maximum values expected in orbit. The following are therefore seen as important considerations in this connection:

a) the linear dynamic range should be as high as possible to make the best use of test data;

b) overloading (however great) of any number of channels must not be allowed to degrade the performance of the remaining channels;

c) linear dynamic range should not be increased AT THE EXPENSE of s/n performance in orbit UNLESS there is some overall benefit, e.g. from much improved calibration; in particular there must be a high enough noise level at the ADC input to overcome quantisation errors.

Gain settings

Past experience has shown it to be undesirable to make signal channel gain settings programmable or adaptive (i.e. by command) in any way as it can easily lead to confusion during testing, complicates ground processing of flight data and significantly complicates the signal channel electronics.

On the other hand, since it is not usually possible to predict (with sufficient accuracy) the effective end-to-end gain of each channel, it is desirable to be able to change the gain setting after initial characterisation. This implies the use of 'select-on-test' gain settings. Once chosen (prior to instrument calibration) these settings would not normally be changed.

Based on the criteria discussed above, the gain setting for each channel should be set to give a nominal (minimum) noise level at the ADC input of around 3 counts rms or 15 counts p-p. The setting would of course have to be lower than this if the resulting maximum in-orbit signal were to exceed about 50,000 counts with a 16-bit Converter, but this is not expected to be the case for any of the HIRDLS channels unless the noise level turns out to be significantly lower than expected.

Signal to noise ratio and analog dynamic range

It is important to appreciate that the NEN figures given in the IRD apply to the output bandwidth of the digital filter (7.5Hz), and not to the ADC input which which has a bandwidth of say 500Hz [TBD]. Thus the 43,000 s/n ratio mentioned in the first para. of this TC (for channel 8) is equivalent to only about 5500 at the ADC input; thus a gain setting which gives 3 counts rms noise would result in a full scale count (including 25% margin) in channel 8 of about 16,500 (plus a suggested zero offset of 1000 counts).

Thus, a 16-bit converter allows a dynamic range margin (before digitiser overflow) of nearly 4:1 in channel 8, to about 115:1 for channel 19. Of course it is not only the ADC which must be linear, but the entire analog 'front-end', from the detector itself to the ADC input, so it is important to consider the relevant factors.

If the use of +/- 15V power rails is assumed, dropping to say +/- 12V after a preamp low-noise filter/regulator, then 18V p-p (i.e. +/- 9V peak) seems comfortable for the maximum linear full-scale AC signal at the preamp output, which would also be the maximum sample-and-hold input, and the maximum ADC input.

For a dynamic range margin of 4:1, the nominal full-scale signal at the ADC input would be 4.5 volts p-p, corresponding to about 70 microvolts per ADC count. For a dynamic range margin of say 100:1, the nominal full-scale signal at the ADC input would be 0.18 volts p-p, corresponding to about 2.8 microvolts per ADC count.

If it were to be determined that the greatest practical sensitivity for the ADC were, say, 10 microvolts per count, then the largest acceptable dynamic range margin would be 28:1. For channels where the theoretical dynamic range could be greater, the gain setting would have to be set higher than that which corresponds to 3 counts rms noise, to ensure at least 10 microvolts per count.

Conclusions

The above discussion may be summarised as follows:

> ensure that gross overloading of many channels cannot affect the performance of the remaining channels;
> make provision for EASY adjustment of gain setting in each signal channel in

steps of say 2% maximum, using select-on-test resistors;
> determine the smallest safe analog signal increment 'da' corresponding to one ADC count;
> choose the nominal (initial) gain setting to give a nominal noise level at the ADC input of about 3 counts rms OR to satisfy the 'da' criterion (whichever is HIGHER) OR to give a minimum dynamic range margin of 25% in orbit (whichever is LOWER)