Gain and Pedestal spread

The gain of the DCD has to be chosen such that a) pedestal spread can be accommodated and b) enough resolution and noise margin remains for an adequate setting of the threshold.

Using:

Dynamic range of DCD: ΔI_{DCD}

Signal Range: I_{sig} (should cover 3 MIPs)

Corrected pedestal spread: $I_P = \Delta I_{DCD} - I_{sig}$

Raw Pedestal spread before 2-Bit DAC correction: $I_{Praw} = 4\ IP = 4\ (\Delta I_{DCD} - I_{sig})$

(assuming that the 2-bit DAC is working fine without non-linearity etc)

With 6000e (most probable) charge for a MIP and $g_q = 0.5$nA/e a MIP is 3µA, or $I_{sig} = 9$µA.

If a pedestal spread of 35µA needs to be covered (Florian's talk): $\Delta I_{DCD} = 35\mu A/4 + 9\mu A = 18\mu A$.

Trivially, the lower the gain the higher the dynamic range. However, at some point it will be difficult to set the threshold: as a rule of thumb, the threshold should exceed 5 σ of the noise, which would be 0.8 ADU, so t > 4 ADU. (Actually, if the noise would be Gaussian a threshold of 3σ is sufficient to reduce the occupancy to ~0.1%. However, in practice there are non Gaussian tails etc . Hence 5σ is on the safe side).

For efficiency reasons the threshold should be below 2000 e- (Checked by Benjamin that this is indeed sufficient)

A 2nd criteria can be obtained demanding that the spatial resolution obtained using charge sharing does not suffer too much by losing pixels of a cluster.

Position by charge sharing: x = p/2 (a-b)/(a+b)

p: pitch (50µm). a charge in right pixel (at x=p/2), b: charge in left pixel (at x= -p/2)

Simplifying: a + b = 1 => x = p/2 (2a-1)

If a pixel with $a < a_t$ is ignored the position is set to –p/2 and the corresponding error is then:

–p/2 – p/2 (2a-1) = a * p.

The rms error in the range of $0 < a < a_t$ is: $\sigma = \sqrt{\frac{1}{a_t}\int_0^{a_t} ap\partial a} = \frac{pa_t}{\sqrt{3}}$

Hence, If a resolution of 10µm with p=50µm should be reached, a_t must be 34% or ~2000e$^-$ (which, by chance, coincides with the value above).

Setting 4 ADU threshold to 2000e one gets a LSB of 500e, or with a g_q of 0.5 nA/e of 0.25 µA.

The dynamic range of the ADC is then be 64µA, the pedestal range as large as 220µA.

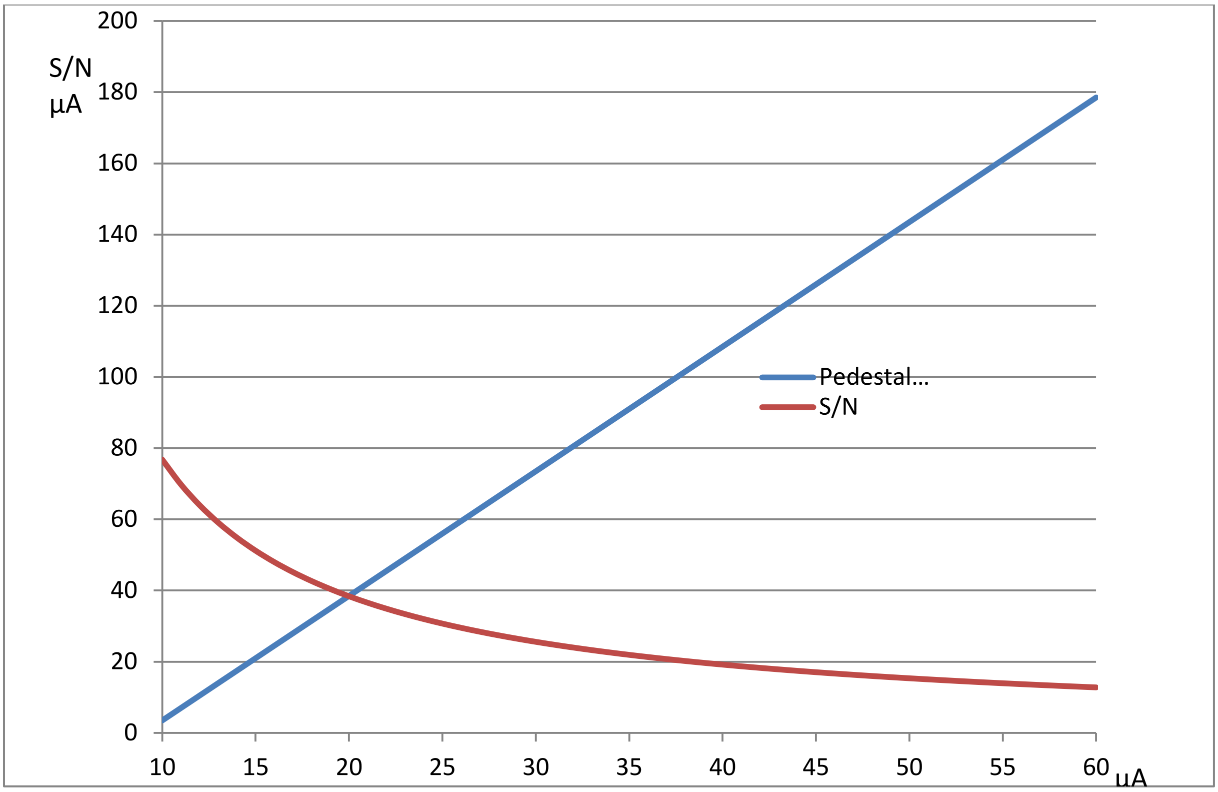
So far nominal values of all parameters were used, in practice more conservative values should be used:

Noise: 1 ADU

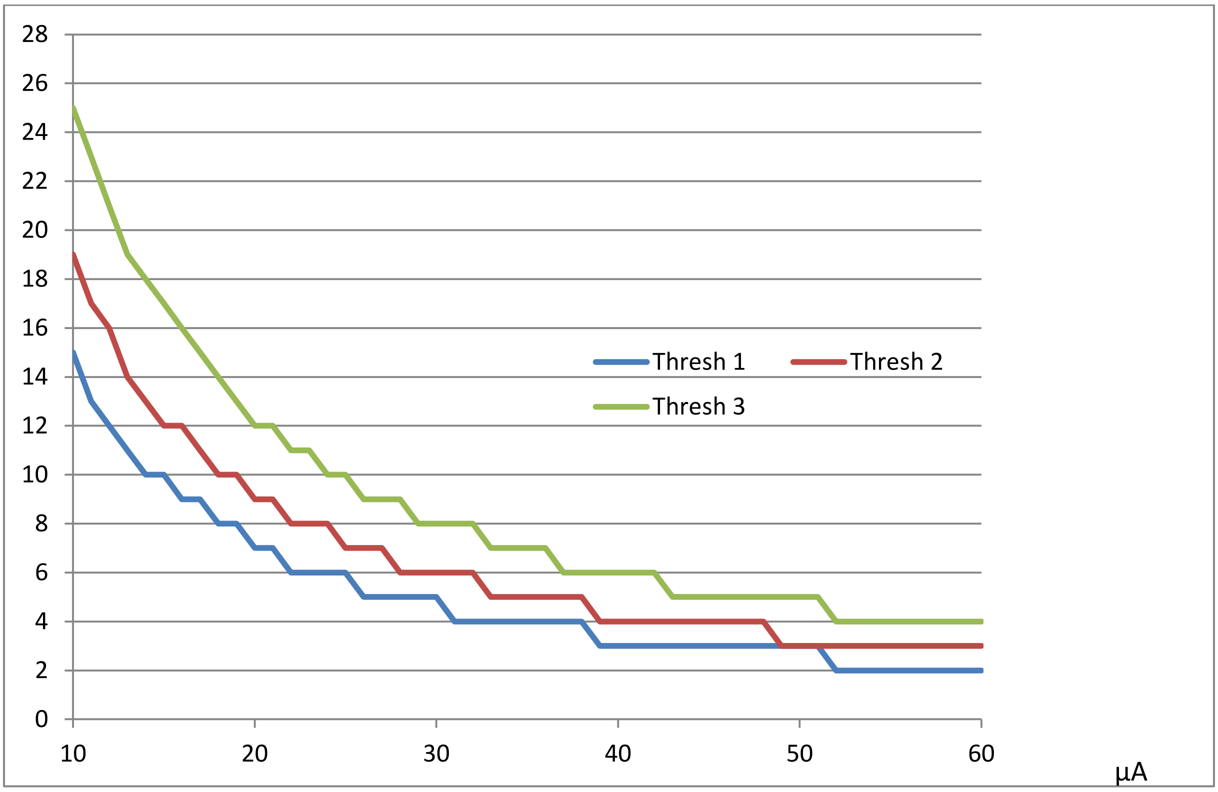
Minimal Threshold: 1500 e- (at least 5 ADU)

Pedestal compression of 2 bit DAC: 3.5 (Florian used 3, but I assume that the performance of the 2-bit DAC gets better if its range is properly chosen).

Pedestal range and S/N for various gain settings are shown in Figure 1, the ADU settings for various thresholds in Figure 2.



Maximal pedestal spread (in µA) versus dynamic range of the DCD (µA) (blue line). The red line indicates the S/N for a MIP.



Threshold in ADU versus DCD dynamic range (in µA). Blue line: 1200 e⁻. Red line: 1500 e⁻. Green line: 2000 e⁻.

To cover a pedestal spread of 35µA a minimum dynamic range of 19 µA is needed. This would then still result in a S/N of 40 and a comfortable threshold of 8 ADU (1200 e).

Raising the threshold to 1500e^- and allowing 5ADU, a dynamic range of ~35 µA can be used, resulting in a maximal pedestal spread of 91 µA (one should take into account, that such a large pedestal spread means large gain differences of the DEPFET pixels, so the assumption of a g_q of 0.5 nA/e might not be valid)

A much lower gain (and therefore increased dynamic range) would lead either to threshold settings below 5 ADU or a higher threshold (2000e^-) risking low efficiency and bad resolution.

The following table lists some values. The actual implementation depends on the spacing of the gain settings in the DCD, but should be in the range given in the table. The values used in the BASF2 simulation are also shown: 25 µA (note: BASF assumes a rather pessimistic noise of 300e^- corresponding to 1.5 ADU counts. This means that the threshold is only 4 times the noise, but in the MC this works since the noise is perfectly Gaussian).

Gain/µA	Max Spread/µA	S/N	1200 e /ADU	1500 e /ADU	2000 e /ADU	LSB/nA
20	38.5	38	7	9	12	78
25	56	31	6	8	7	98
30	73.5	26	5	6	8	117
35	91	22	4	5	7	137
40	109	19	3	4	5	156
25	56	20	6			100

Table 1: Some values for Gain, maximal pedestal spread, S/N and ADU values of certain thresholds. The last (grey) line corresponds to the values used in BASF2.

Assuming an ADC range of 35µA allowing for 91µA pedestal spread, the pedestal compression the range of the two bit DAC needs to be 91µA*3/4 = 68µA (plus some safety margin).

Note: large pedestal spreads due to inhomogeneous irradiations along z should show a ‘common mode’ like structure and can be compensated by the input common mode correction (range?).