Analog readout channel

Minimum threshold setting

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Noise Hit Rate

- In a binary system the electronic noise is of great importance in selecting the threshold needed to discriminate between an output generated by noise and a genuine signal
- The noise hit rate (nhr) can be written as

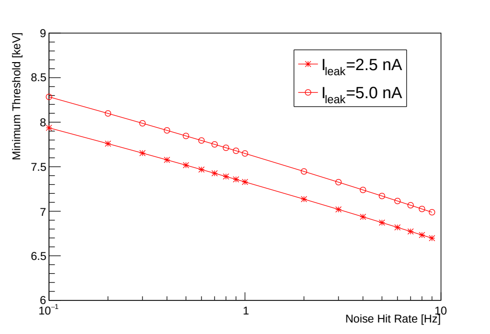
$$\boxed{f_n = \frac{f_0}{2} exp\left(-\frac{Q_{th}^2}{2ENC^2}\right)}$$

- f_0 is the noise hit rate at zero threshold
(function of: shaping, S_w, $S_{1/f}$, t_p, I_{leak}, C_D, inter-strip capacitance)
- Q_{th} is the threshold referred to the input in unit of charge
- ENC is the equivalent noise charge

Minimum threshold as a function of the NHR

A minimum threshold value ($Q_{th,min}$) can be found for all the channels to satisfy the requirement on the maximum noise hit rate ($f_{n,max}$)

$$\boxed{Q_{th,nhr} \geq ENC\sqrt{2 \cdot ln\left(\frac{f_0}{f_{n,max}}\right)}}$$



NHR=1 Hz (≈1% of event rate) with threshold 7.7 keV @ I_{leak}=5 nA

Results obtained @ t_p=700 ns and C_D=42 pF (no interstrip capacitance)

Comparator Threshold Dispersion

- In order to limit the number of channels exceeding the maximum NHR, the comparator threshold dispersion should be taken into account
- The minimum threshold has to be increased according to

$$\boxed{Q_{th,disp} \geq \lambda\left(n_{ch,max}\right) \cdot \frac{\sigma_{V_{Th}}}{G_Q}}$$

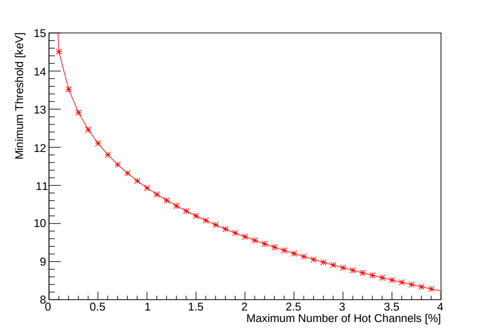
- $\sigma_{V_{Th}}$ is the standard deviation of the threshold dispersion
- G_Q is the charge sensitivity
- $n_{ch,max}$ is the maximum acceptable fraction of hot channels
- λ should be chosen such that

$$\lambda\left(n_{ch,max}\right) = \sqrt{2} \cdot Erfc^{-1}(2n_{ch,max})$$

where $Erfc(x)$ is the complementary error function

Minimum threshold as a function of the hot channels

- $\sigma_{V_{Th}}$=1.4 mV standard deviation of the threshold dispersion (not yet optimized)
- G_Q=0.3 mV/keV charge sensitivity



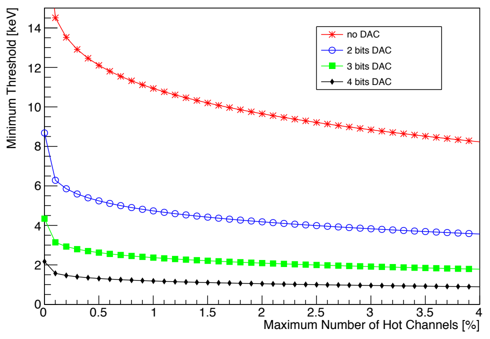
2% of hot channels is obtained with a threshold $\geq$9.65 keV

Comparator Threshold Dispersion Correction [1]

Threshold dispersion could be reduced by fine trimming it with a local DAC

- the DAC should be able to span a range of $6 \cdot \sigma_{V_{Th}}$
- this results in a tuned threshold dispersion (n = bits of the DAC)

$$\boxed{\sigma'_{V_{Th}} \approx \frac{6 \cdot \sigma_{V_{Th}}}{2^n \sqrt{12}}}$$



[1] L. Ratti, A. Manazza, “Optimum Design of DACs for Threshold Correction in Multichannel Processors for Radiation Detectors”, *IEEE TNS*, 2012

Summary

To comply with both noise hit rate and comparator threshold dispersion the minimum threshold must be set at

$$\boxed{Q_{th,min} \geq Q_{th,nhr} + Q_{th,disp}}$$

By assuming

- a maximum noise hit rate of 1 Hz (1% of the event rate)
- a maximum fraction of 2% of hot channels

the minimum threshold must be placed at

DAC bit	Threshold [keV]
0	17.3 keV
2	11.9 keV
3	9.8 keV
4	8.8 keV