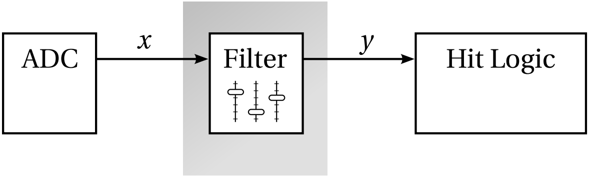
SPADIC 1.0 Digital Signal Processing

Michael Krieger

CBM FEE/DAQ Workshop
January 26, 2012

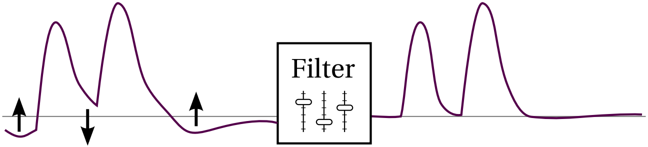
New in SPADIC 1.0

- digital filter
- 4 stages
- 16 bit resolution
- programmable coefficients



Why?

- prevent pile-up
  - separate individual pulses (“ion tail cancellation”)
  - help hit logic to work properly
- eliminate low-frequency baseline fluctuations
- add flexibility → adapt to detector characteristics

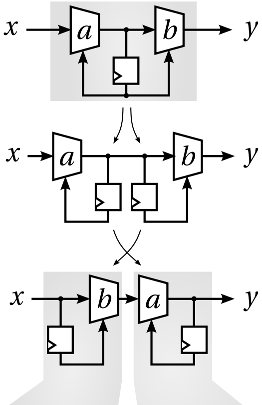


one filter stage

actual implementation:

split:

swap:

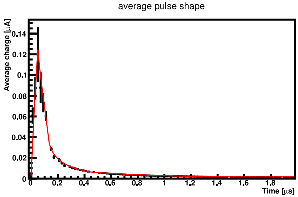


$$x[n] + bx[n-1] + ay[n-1] = y[n]$$

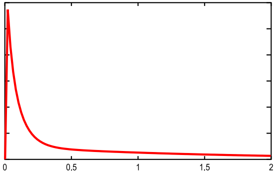
Finding the output signal

- numerically: use recursive definition
  $y[n] = x[n] + bx[n-1] + ay[n-1]$
- analytically: $\mathcal{Z}$-transform translates into multiplication
  $\mathcal{Z}\{y\} = H \cdot \mathcal{Z}\{x\}$
- transfer function
  $H(z) = \frac{1+bz^{-1}}{1-az^{-1}}$

- $\mathcal{Z}$-transform relatively easy with exponential functions
- model the signal as weighted sum of exponential terms:
  $x[n] = \sum w_i e^{-nT/\tau_i} = \sum w_i q_i^n \quad (0 \le q_i \le 1)$



data by C. Bergmann & D. Emschermann

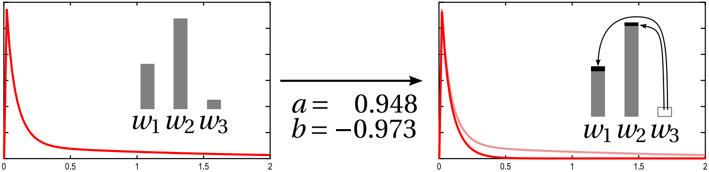


$w_1 = 0.5, \tau_1 = 30\,\text{ns}, (q_1 = 0.264)$
$w_2 = 1.0, \tau_2 = 90\,\text{ns}, (q_2 = 0.641)$
$w_3 = 0.1, \tau_3 = 1.5\,\mu\text{s}, (q_3 = 0.973)$

- get the real signal by convolution with shaper impulse response
- can be ignored: $H_{\text{filter}}(H_{\text{shaper}}\mathcal{Z}\{x\}) = H_{\text{shaper}}(H_{\text{filter}}\mathcal{Z}\{x\})$

Tail cancellation

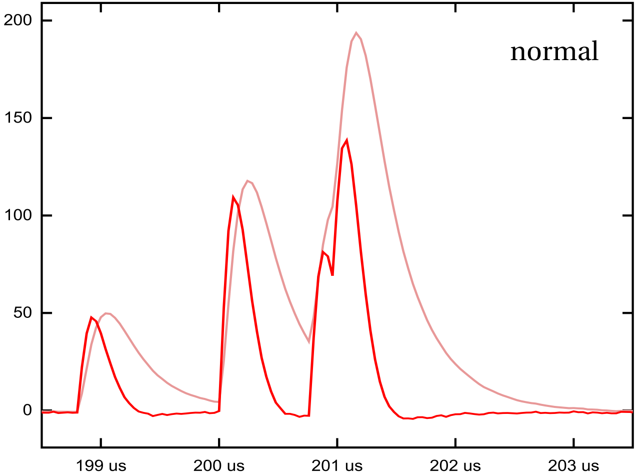
- filter stage transfers relative weights w_i between terms
- one exponential term can be eliminated



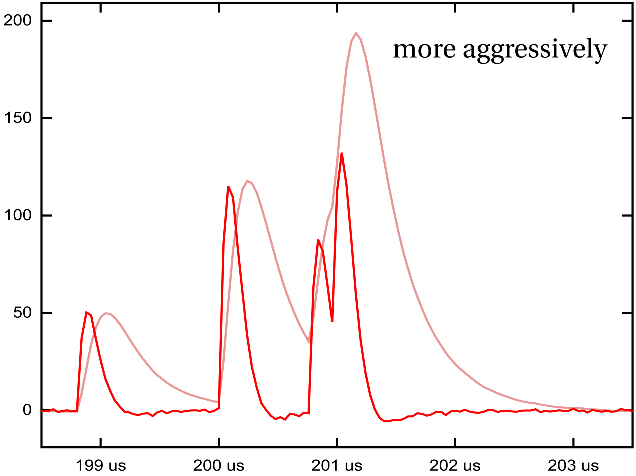
useful coefficient range

- $-1 \leq b < 0, \quad 0 \leq a < 1$
- $|a| < |b| \quad \Leftrightarrow \quad 0 \leq a < -b \leq 1$
- simple/extreme case: $a = 0, b = -1 \Rightarrow y[n] = x[n] - x[n-1]$

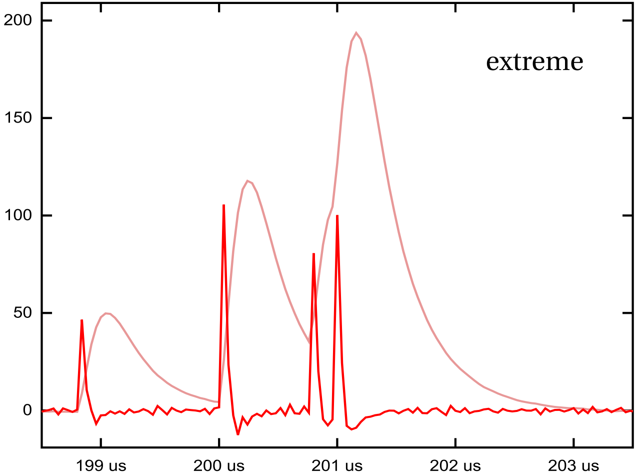
Examples



Examples


more aggressively
200
150
100
50
0
199 us
200 us
201 us
202 us
203 us

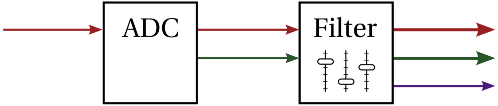
Examples



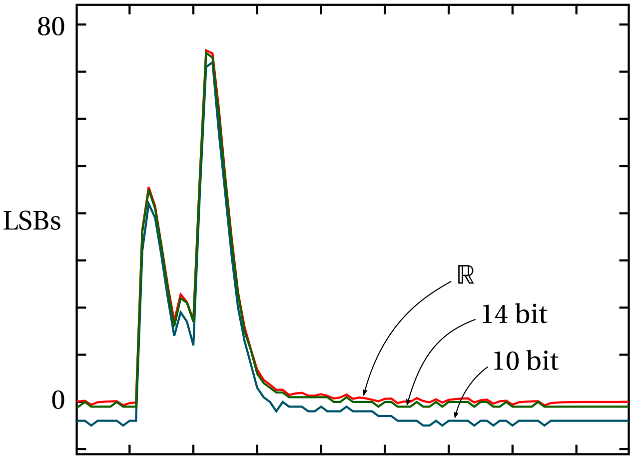
Limitations

Noise / Quantization error

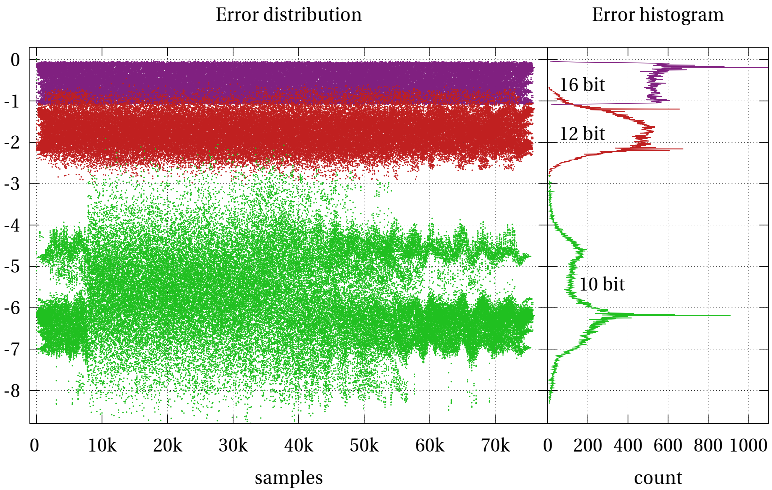
- filter has high-pass characteristic
- noise present in signal gets emphasized
  - analog noise + ADC quantization error
  - forces tradeoff
- filter introduces additional quantization error



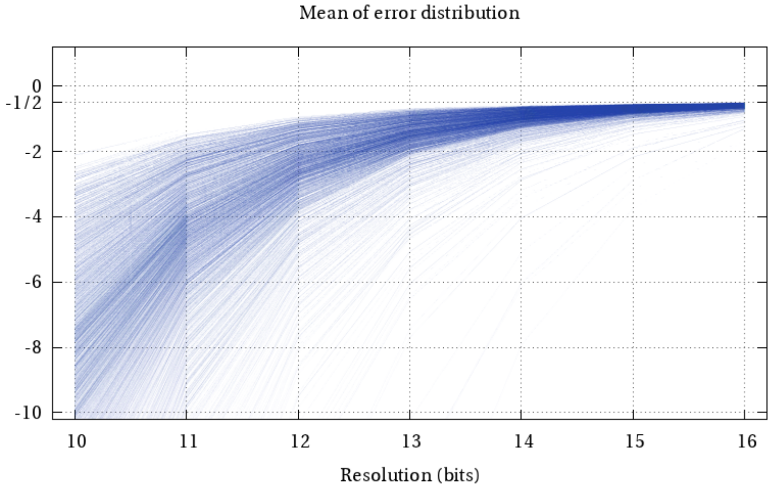
Quantization error



Quantization error: simulations



Quantization error: simulations



Quantization error: simulations