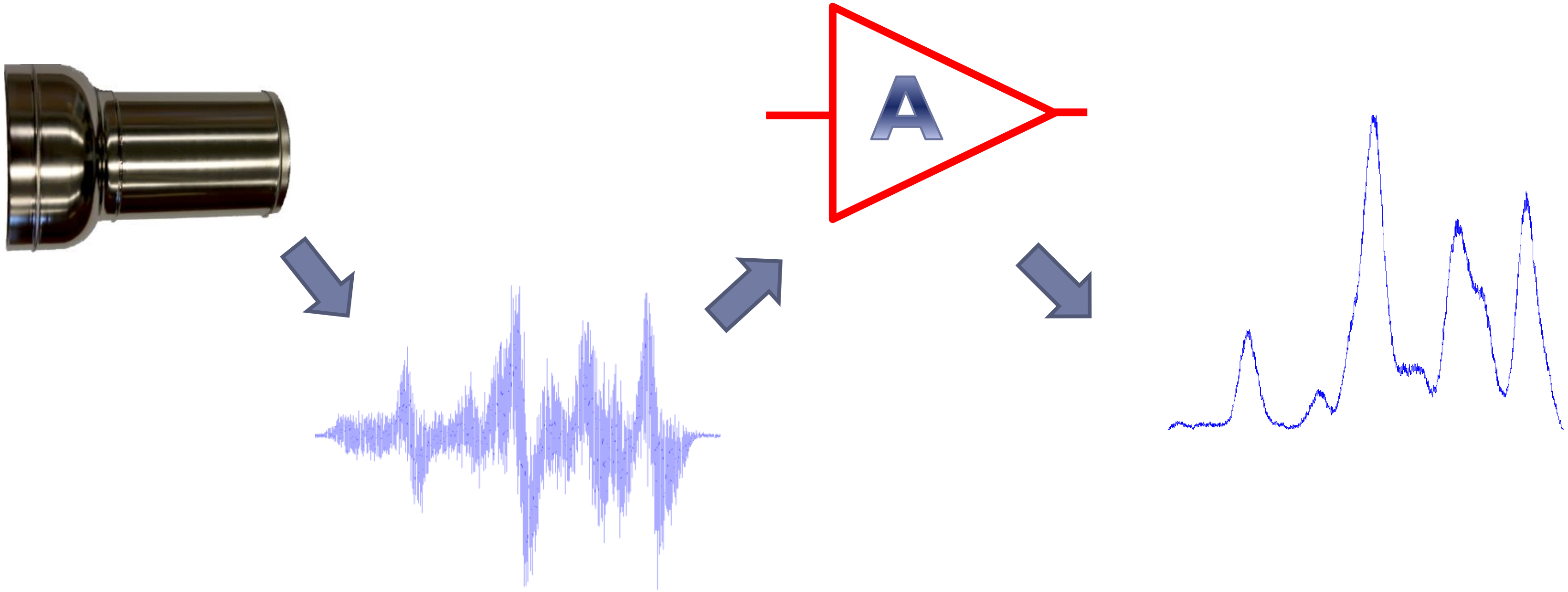


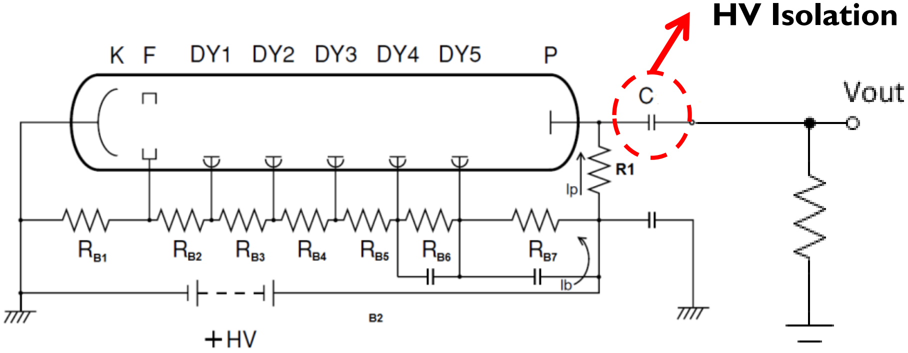
ENERGY PLANE
FRONT END ELECTRONICS

Canfranc May - 2016

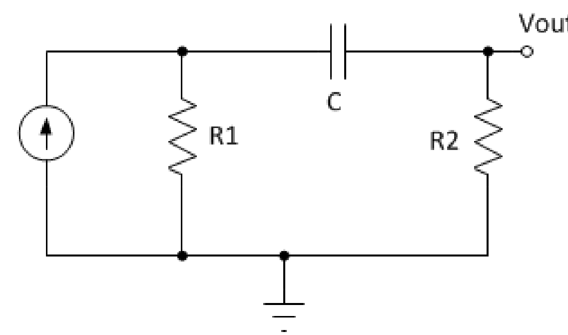
PMT – Connection Mode

- Grounded Cathode

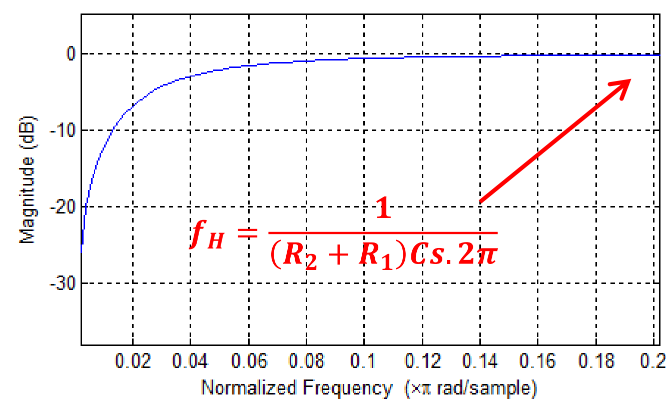
AC Coupling
HV Isolation needed



Conceptual Equivalent Circuit



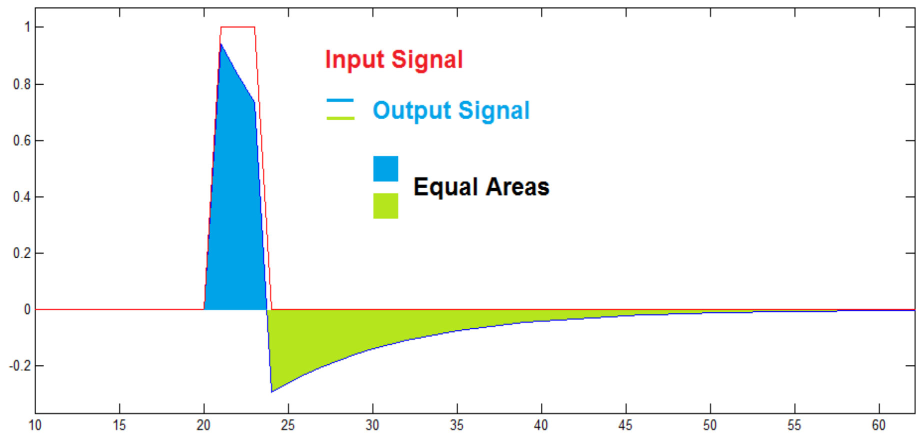
$$\frac{V_{out}}{I_i} = \left({}^{R_2}/_{R_1}\right)\frac{(R_2 + R_1)Cs}{(R_2 + R_1)Cs + 1}$$



* Hamamatsu PMT Handbook

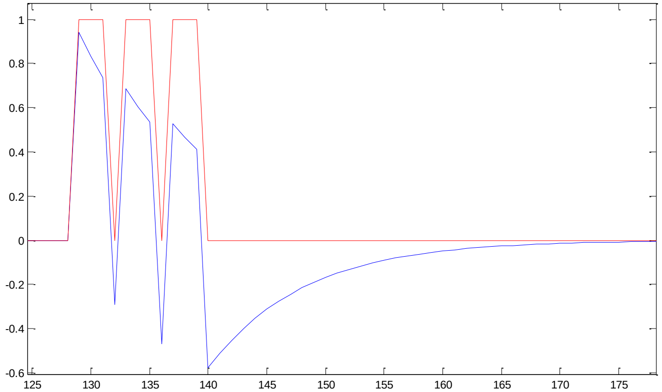
Coupling Capacitor Side Effects

- Baseline Shift – Energy Resolution Effect in long signals (I)



Energy resolution for a Single Pulse is fine
(although pulse length is longer)

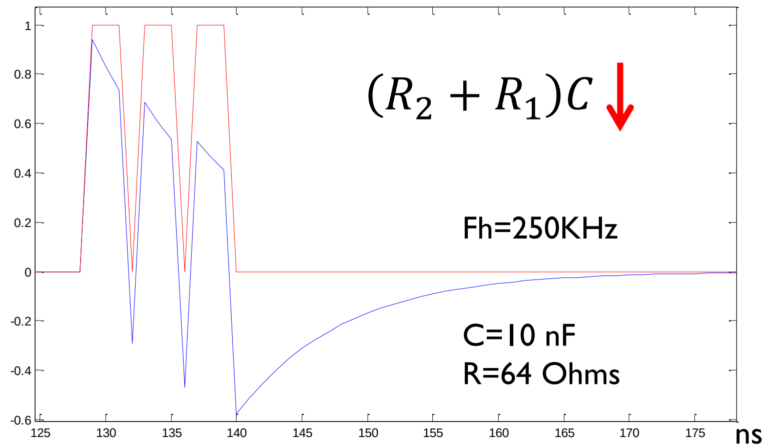
However, energy measurement based on area in long multipulse signals gets distorted by baseline shift.



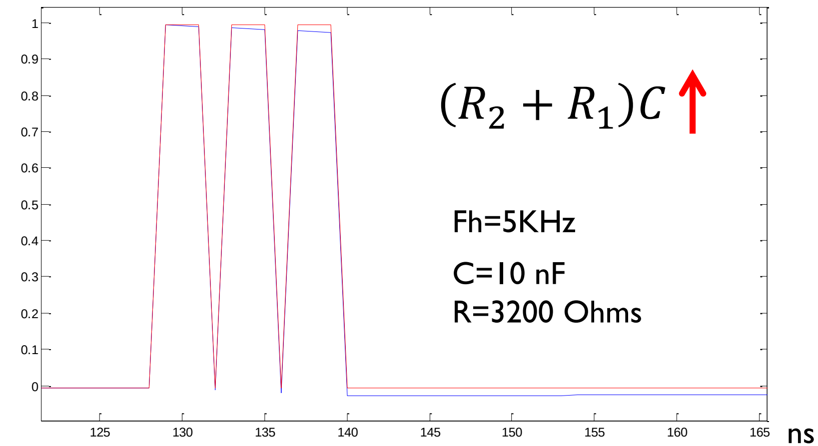
Example: Total area including positive and negative lobes predicts 2.28 energy pulses

Coupling Capacitor Side Effects

- Baseline Shift – Energy Resolution Effect in long signals (II)



~24% Energy Res

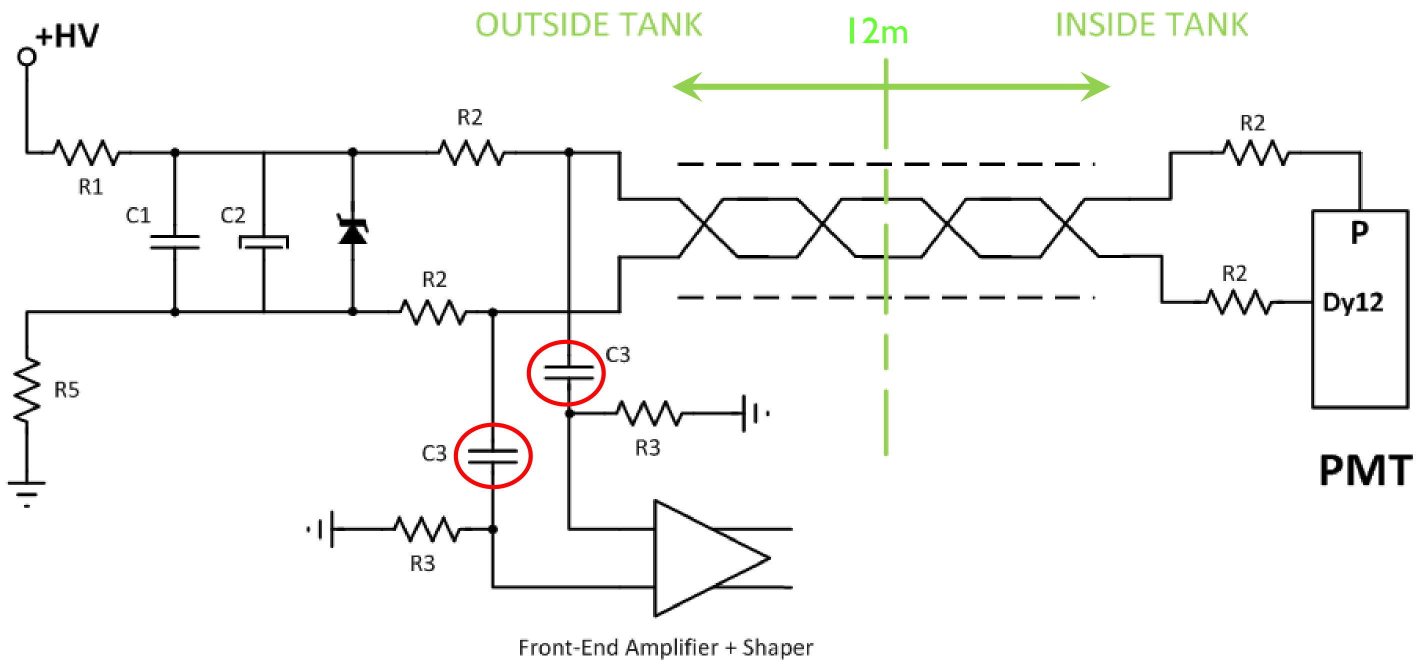


~2% Energy Res

Longer time constants relieve the loss in resolution
However **high value HV Capacitors** are **difficult to find** and **big Resistors** introduce **thermal noise** issues

Front End Concept

- Based on David Nygren's proposal.



- ✓ P – Dy12 connection generates a pseudo-differential signal (increases induced noise inmunity)
- ✓ R2 differential impedance matching (PMT ringing)
- ✓ Signal is generated by i(P) & i(Dy12) in R2
- ✓ R3 * C3 - A high HPF time constant will keep C3 from discharging thus reducing Baseline Shift

The "Oscilloscope" Solution

- Coupling Capacitor Side Effects. Design Trade-Offs

  - *PMT – Single Photo Electron response*

PM_GAIN	4,50E+06	
SPE_length	5,5	ns
SPE_Imax*	26	uA
SPE_charge	0,7	pC
SPE_in_V*	1,61	mV

* Due to FE Filtering Effect

*Zin = 124 (1/2 Match Loss)

  - *DAQ Facts*

BANDWIDTH	10	MHz
ADC Dynamic Range	2	V
ADC_bits	12	
ADC_LSB	0,49	mV
ADC_Gain	1,25	
SPE_ADC	7,35	mV
SPE_LSB	15	

FRONT END BASIC SPECS

SPE_LSB	15	
SPE_FE_out	5,88	mV
LSB_FE_out	0,392	mV
GAIN	226,5	Vout / Iin

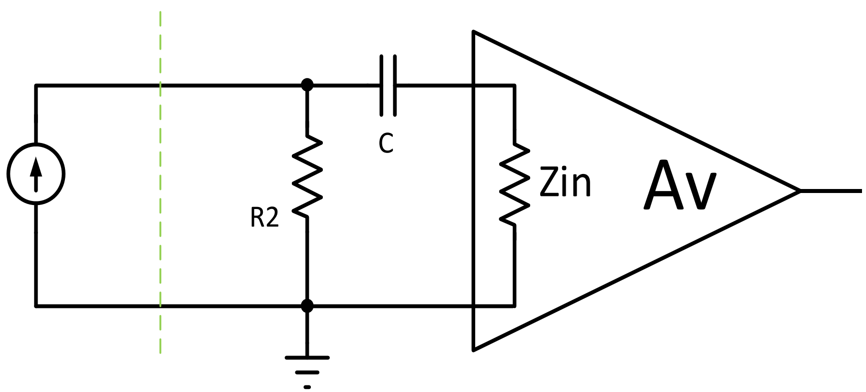
Noise(rms) should be kept under 1/2 LSB

Including R2 (Av ≈ 4)

The "Oscilloscope" Solution

- Coupling Capacitor Side Effects. Design Trade-Offs

Conceptual Equivalent Circuit

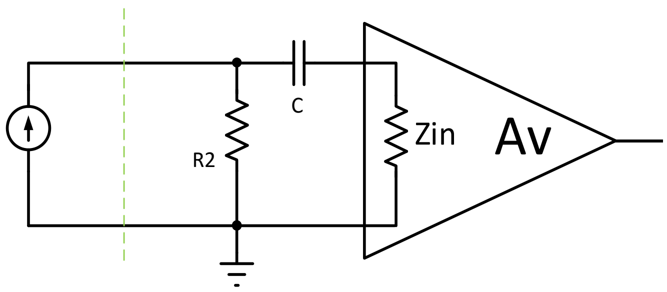


Pseudo Diff. introduces a remarkable Common Mode to be matched at the Amplifier.

SRF of Coupling capacitor should be higher than the expected Bandwidth of the FE
→ Polypropilene / Ceramic CG0 up to 10 nF are commercially available

The "Oscilloscope" Solution

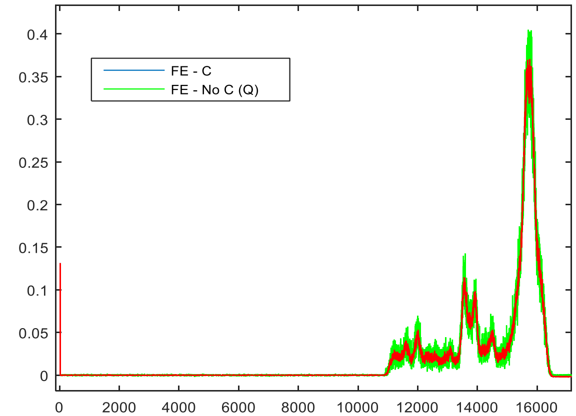
- Coupling Capacitor Side Effects. Design Trade-Offs



The **higher the value of Zin** the **lower the baseline shift effect** in Energy measurement.

However **high values of Zin will increase thermal noise** of the FE

A **generic FE model** has been developed which includes coupling, C shaping, DAQ quantization, finite precision effects and noise.



Simulations show that a **fhmin lower than 10 Hz** is needed for a **Energy Resolution better than 1%**

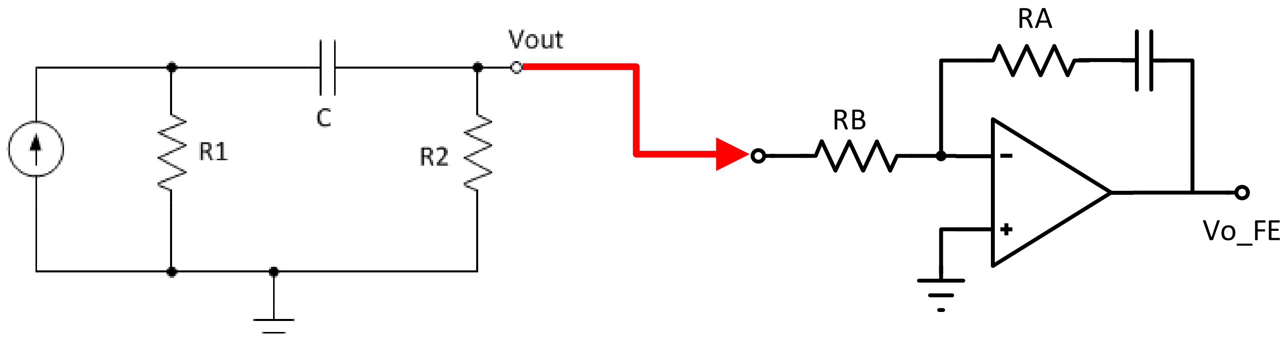
→ C = 10 nF // Zin = 1.6 M

Thermal Noise (FE OUT) > 2 mVrms ≈ 5 LSB

(only the Zin noise considered)

Analog BLR Solution

- CONCEPT: **Try to fix the Coupling Capacitor effect afterwards**



$$\frac{V_{out}}{I_i} = \left({}^{R_2}/_{R_1}\right)\frac{(R_2 + R_1)Cs}{(R_2 + R_1)Cs + 1}$$

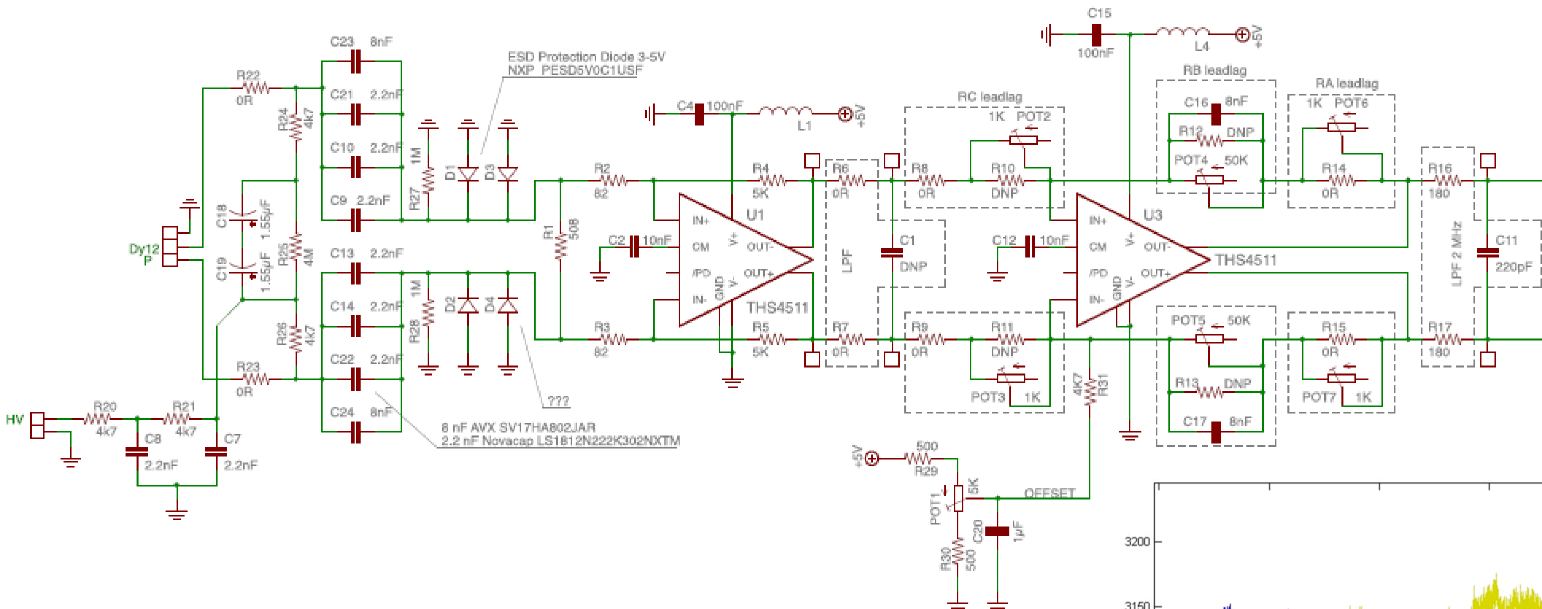
$$\frac{V_{out\_FE}}{V_{out}} = \frac{(R_A)Cs + 1}{(R_B)Cs} = \frac{R_A}{R_B} + \frac{1}{R_B Cs}$$

$$X(t) * H(t) = Y(t) \longrightarrow Y(t) * H^{-1}(t) = X(t)$$

RA and RB can be designed so that the effect of the Coupling C is nullified

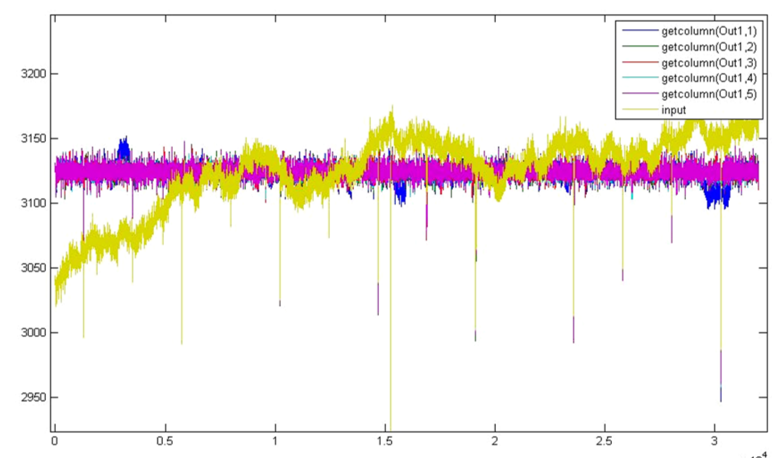
Analog BLR Solution

- CONCEPT: **Try to fix the Coupling Capacitor effect afterwards**



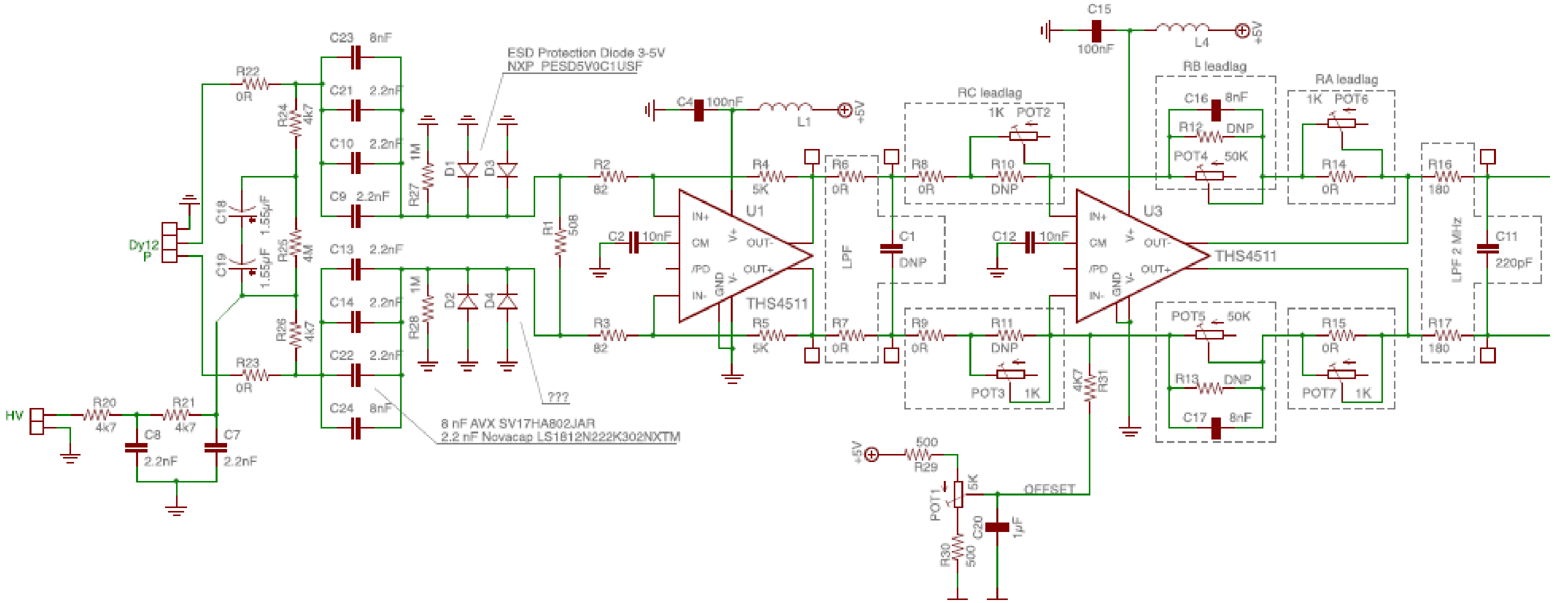
BLR is a **Continuous Time** Integrator → Low Frequency noise expected

This is solved at the DAQ stage using a sliding window mean filter



Analog BLR Solution

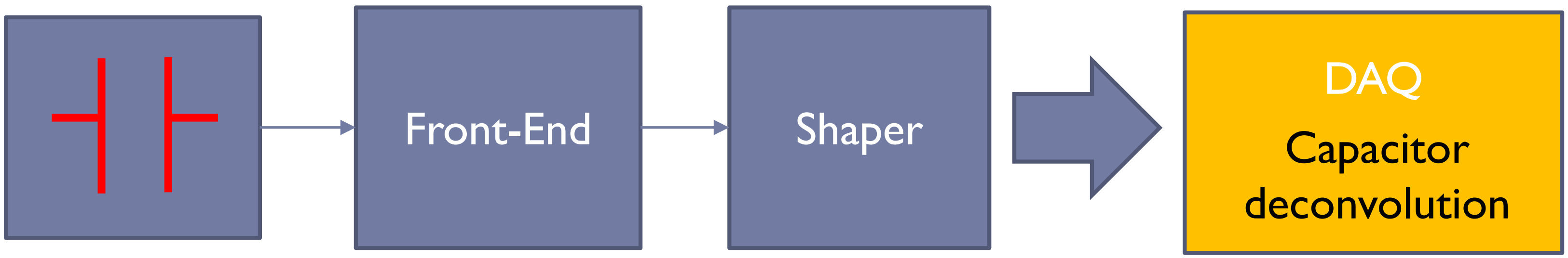
- CONCEPT: **Try to fix the Coupling Capacitor effect afterwards**



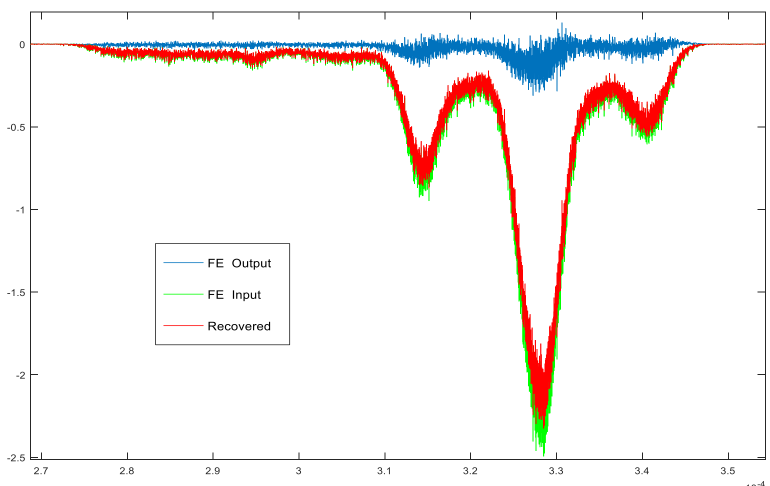
BAD NEWS:
- BLR extremely difficult to trim.
- Long tails due to inaccurate pole/zero cancellation.
- BLR effect is limited to a few microseconds (no clean compensation for long pulses)

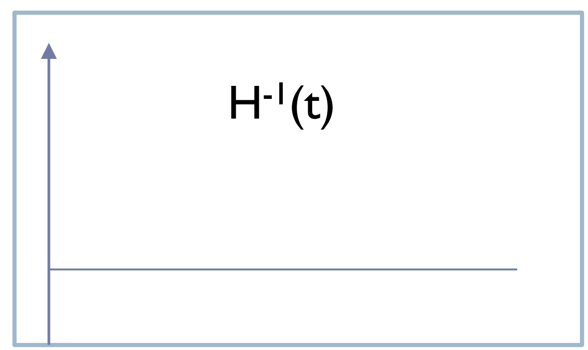
Two Sides Solution

- Moderate RC + Digital BLR



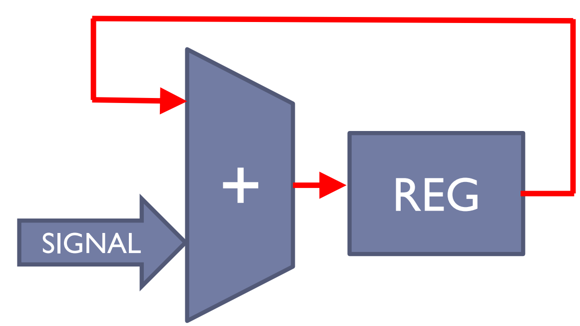
FE model with Coupling C, shaping, DAQ quantization, finite precision effects and noise.





Two Sides Solution

- Moderate RC + Digital BLR
  - IMPROVEMENTS:
    - Zin*C time constant (f_{HPB}) can be relaxed → **Lower Zin → Lower NOISE**
    - Digital BLR can be switched off when no signal is detected and switched on when pulses are detected using a threshold → **No LF noise**
    - Digital BLR implementation is very simple. NO NEED to use a FIR (MAC unit).



Two Sides Solution

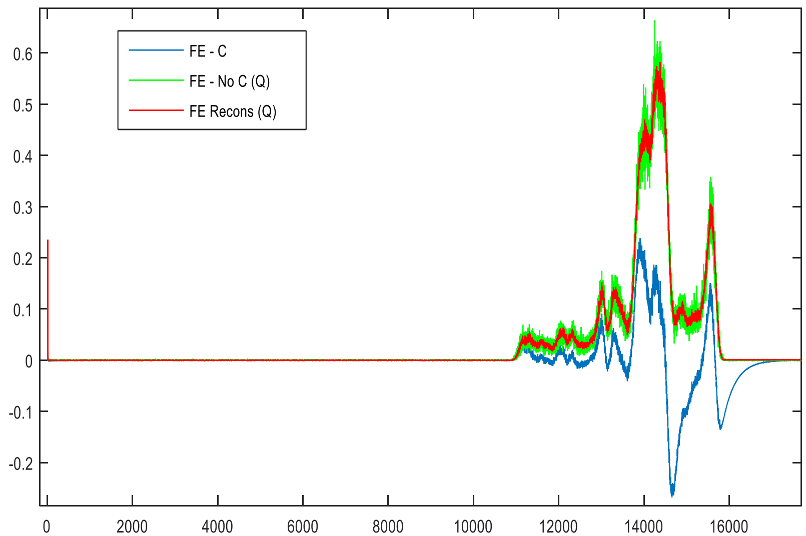
- PRELIMINARY RESULTS (Simulated)
  - The Zin can be downsized to 2100 Ohms with this results:

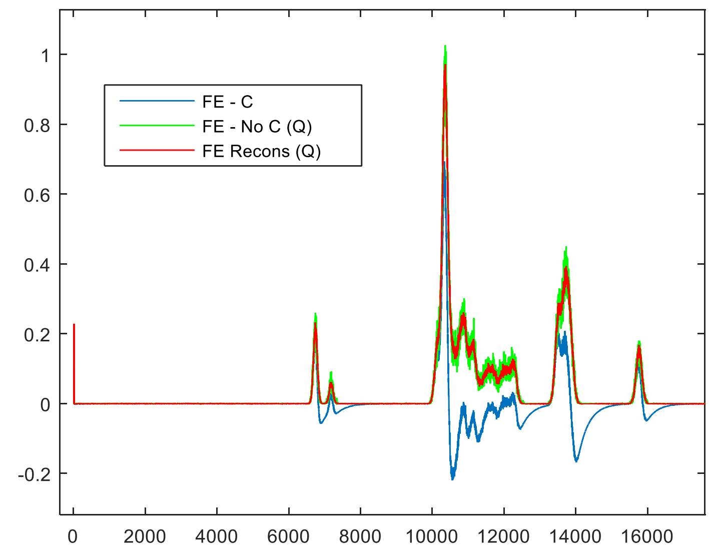
Thermal Noise* (FE OUT) < 0.17 mVrms ≈ 0.43 LSB

Estimated Energy Measurement Error < 0.64 %

* Fully-Diff Opamp Config. All noise sources considered

SPECS FULFILLED !!!





Further Improvement

- Anode Preamp + Fully Differential Mode Transmission