# Ideas on low noise preamp with controlled Zi

Calorimeter Electronics Upgrade - LAL - April 8th 2009

# Outline

I. Requirements

II. Noise

III. Feedback amplifiers

IV. Cable coupled

# I. Specifications PMT gain must be reduced by a factor 4-5

| | Value | Comments |
|---|---|---|
| **Energy range** | 0-10 GeV/c (ECAL) | 1-3 Kphe / GeV |
| **Calibration** | 4 fC /2.5 MeV / ADC cnt | 4 fC input of FE card: assuming 25 Ω clipping at,PMT base<br>12 fC / ADC count if no clipping |
| **Dynamic range** | 4096-256=3840 cnts :12 bit | Enough? New physic req.?<br>Pedestal variation? |
| **Noise** | <≈1 ADC cnt or ENC < 5 -6 fC | < 1 nV/√Hz ? |
| **Termination** | 50 ± 5 Ω | Passive vs. active |
| **AC coupling** | Needed | Low freq. (pick-up) noise |
| **Baseline shift prevention** | Dynamic pedestal subtraction (also needed for LF pick-up) | How to compute baseline?<br>Number of samples needed? |
| **Max. peak current** | 4-5 mA over 25 Ω | 50 pC charge at PMT output |
| **Spill over correction** | Clipping | Residue level: 2 % ± 1 % ? |
| **Spill over noise** | << ADC cnt | Relevant after clipping? |
| **Linearity** | < 1% | |
| **Crosstalk** | < 0.5 % | |
| **Timing** | Individual (per channel) | PMT dependent |

# II. Noise computation

- Total noise power (or variance) at the output preamplifier (gain A, time constant τ) + integrator (time constant $\tau_i$, integration time T):

$$\psi^2_{white}\left(t_0 = t_1 + T\right) = \frac{1}{2} e^2_{ni\,white} \left(\frac{A}{\tau_i}\right)^2 \left(T - \tau\left(1 - e^{-\frac{T}{\tau}}\right)\right) \simeq\Big|_{T \gg \tau} \frac{1}{2} e^2_{ni\,white} \left(\frac{A}{\tau_i}\right)^2 T$$

- Signal at the end of integration ($\tau_s$ is signal decay time):

$$v_o\left(t = T\right) = R_{PMT} \frac{A}{\tau_i} Q \left(1 - e^{-\frac{T}{\tau_s}}\right) \simeq\Big|_{CLIPPING} R_{PMT} \frac{A}{\tau_i} Q$$

- Then, for √noise power = signal of $Q_{LSB}$

$$e_{ni\,white} < \frac{R_{PMT} Q_{LSB}}{\sqrt{T/2}} \simeq \frac{17\Omega \cdot 5\,fC}{\sqrt{25ns/2}} \simeq 0.75 \frac{nV}{\sqrt{Hz}}$$

Clipping impedance // 50 Ω

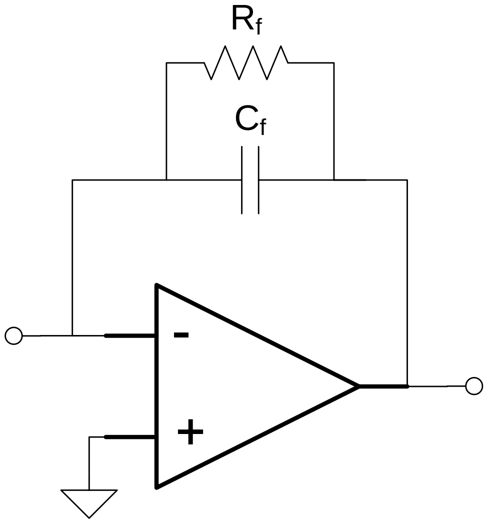
- For a line adaptation (50 Ω) noise requirement is relaxed to 2 nV/√Hz
- Additional shaping (delay line int. reset or any high pass filter) was not taken into account, it will improve (a little bit): LF is removed

# III. Feedback amplifiers

- Electronically cooled termination:
  - Transimpedance amplifier
  - Charge amplifier if clipping in base

$$Z_i(j\omega) \simeq R_f \frac{\frac{GBW}{G_0} + j\omega}{GBW} \simeq \Big|_{\frac{GBW}{G_0} << \omega} \frac{R_f}{G_0}$$

- Dominant pole of the amplifier should be higher than BW of the signal $\frac{GBW}{G_0} \equiv \omega_d >> BW$
- Input impedance is inductive: stability



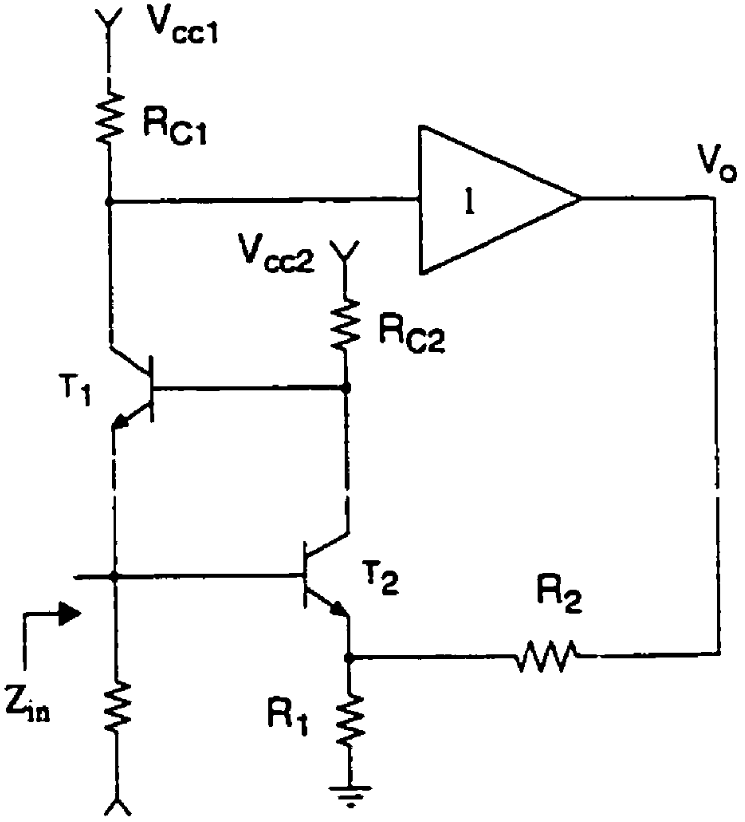
- Low noise:
  - Amplifier can be optimized
  - Rf contributes to parallel noise, if larg enough it is negligible
- Input impedance depend on open-loop properties of the amplifier:
  - Can controlled to the few % level in ASIC

# IV. Cable coupled amplifier (ATLAS LAr style)

- Common gate with double feedback
  - Inner loop to reduce input impedance preserving linearity and with low noise
  - Outer loop to control the input impedance accurately

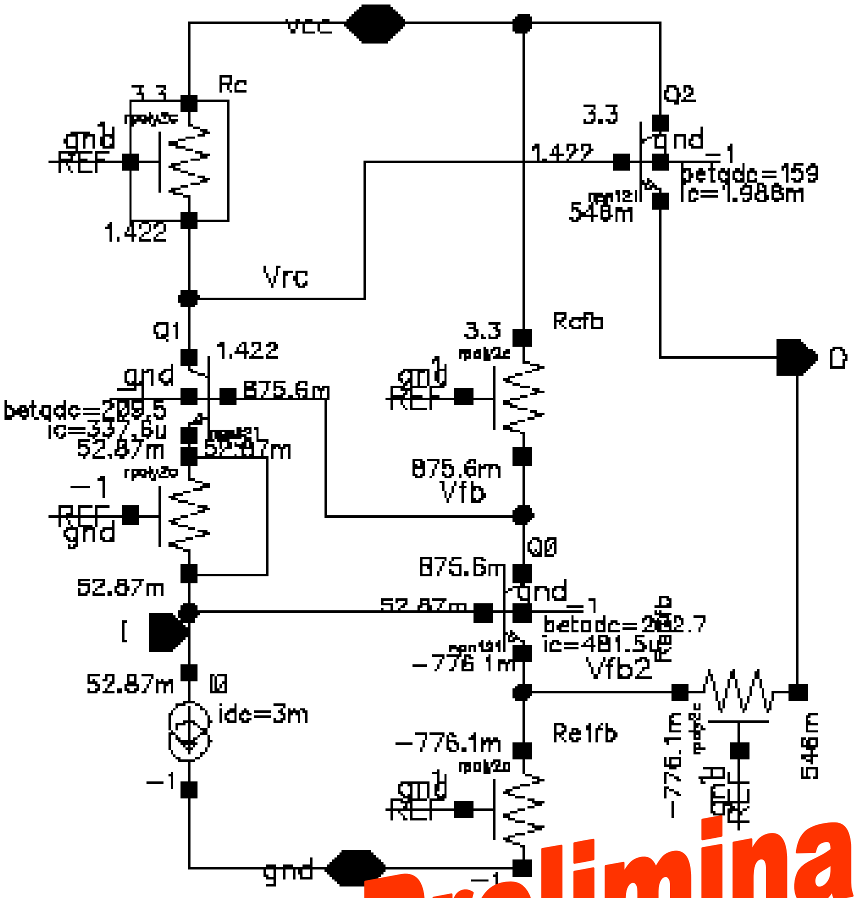
$$Z_i(j\omega) \simeq \frac{1/g_{m1}}{G} + R_{C1}\frac{R_1}{R_1+R_2}$$

- Transimpedance gain is given by $R_{C1}$
- Noise is < 0.5 nV/sqrt(Hz)
  - Small value for $R_1$ and $R_2$
  - Large $g_{m1}$ and $g_{m2}$



# IV. Cable coupled amplifier

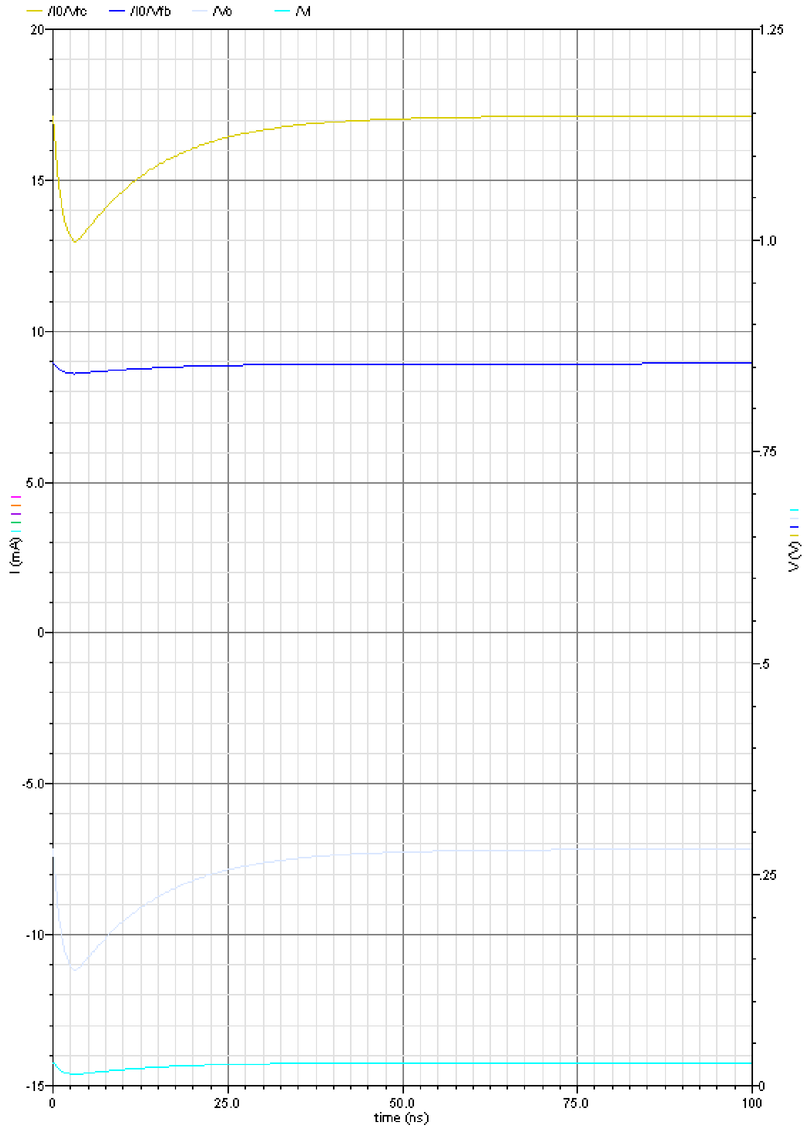
- Some simulations in SiGe 0.35 μm CMOS (AMS)

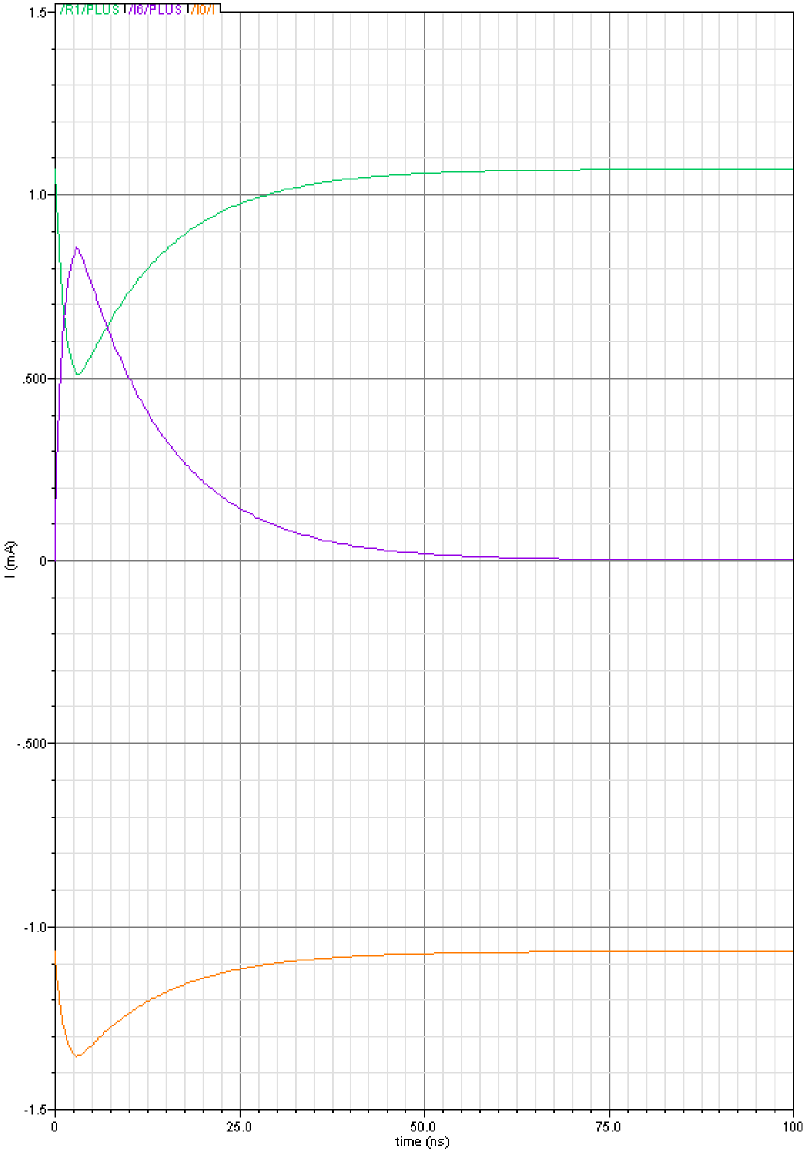


Preliminary (very)

# IV. Cable coupled amplifier

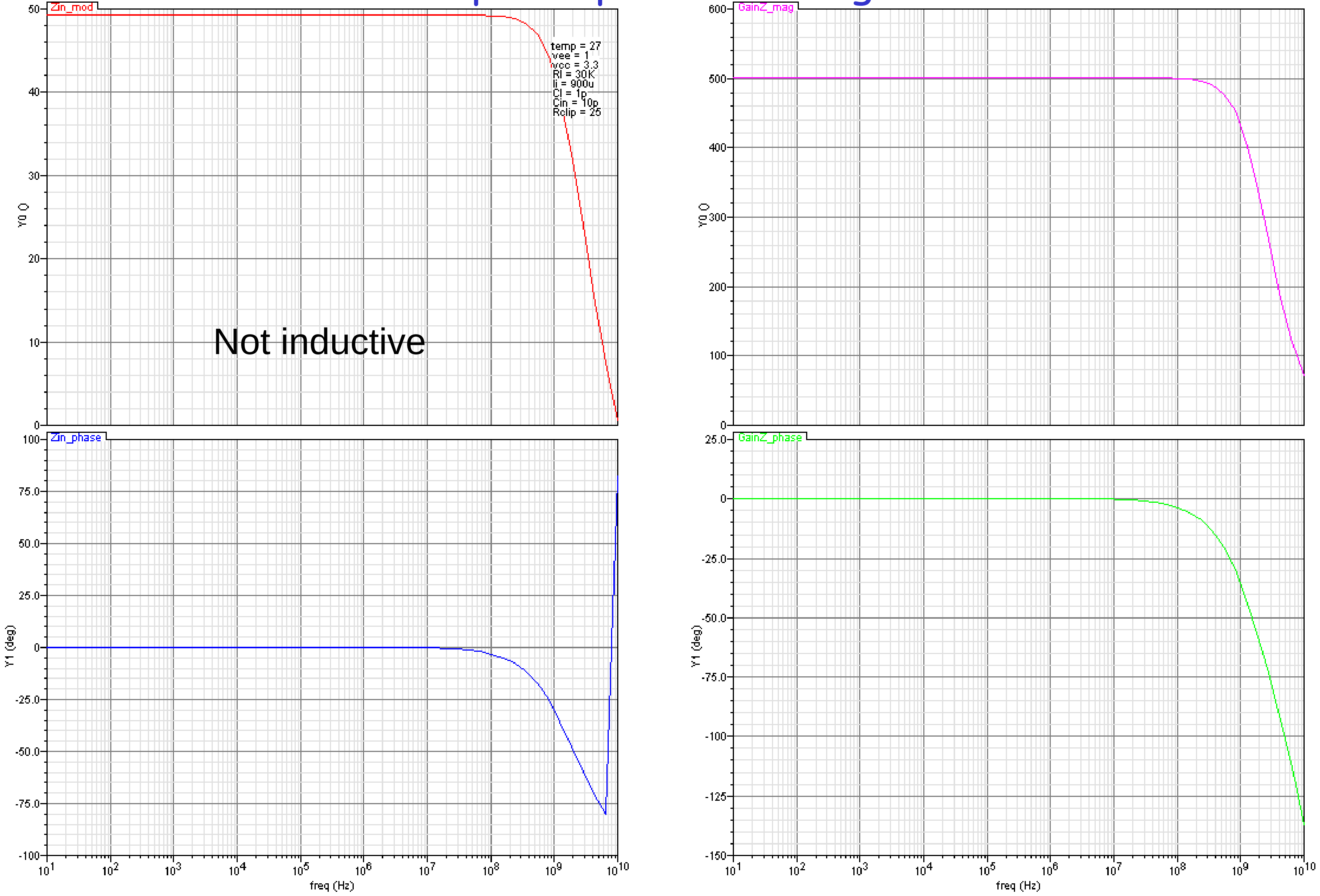
- Transient simulation





# IV. Cable coupled amplifier

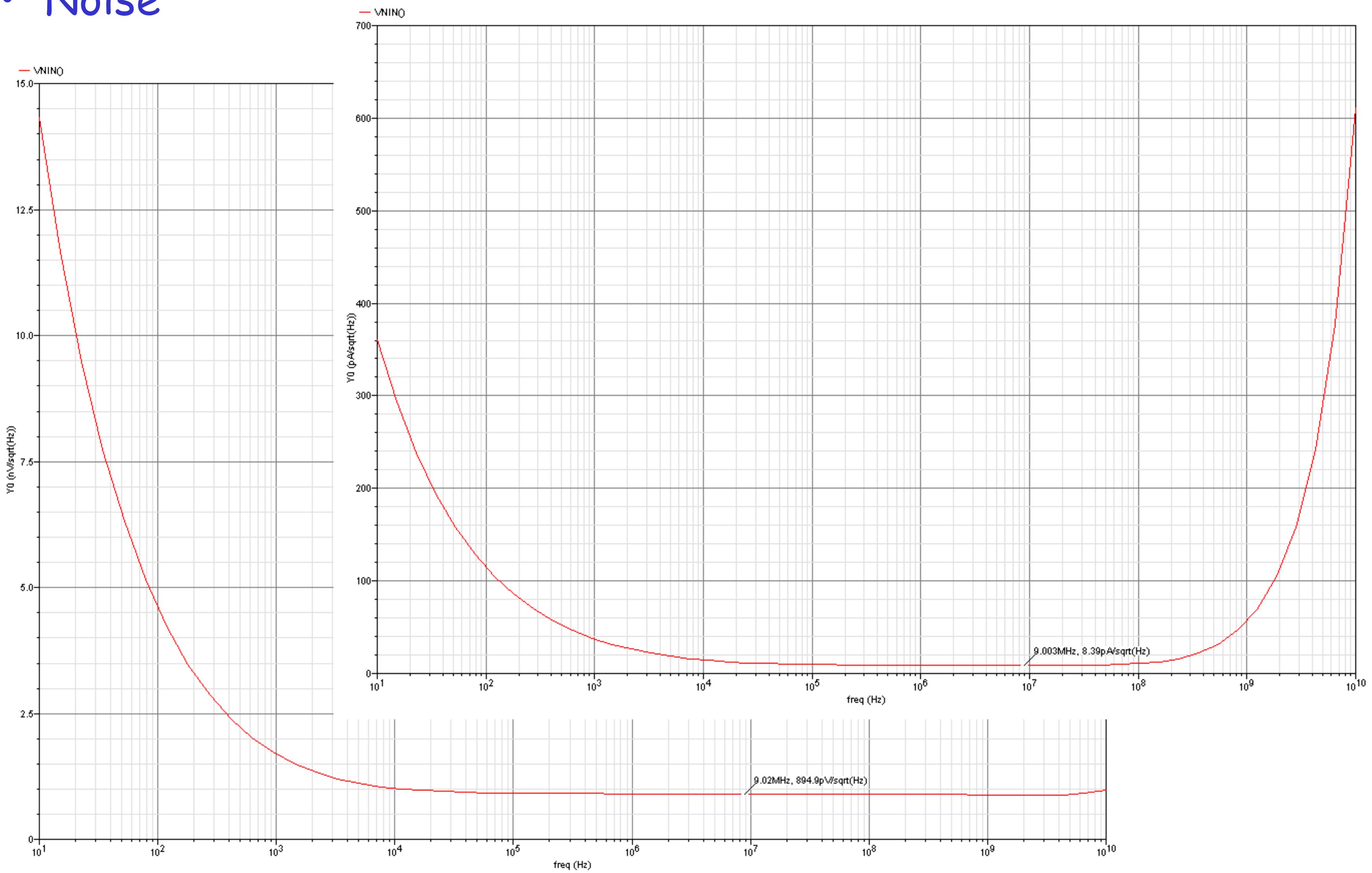
- Input impedance and gain



Not inductive

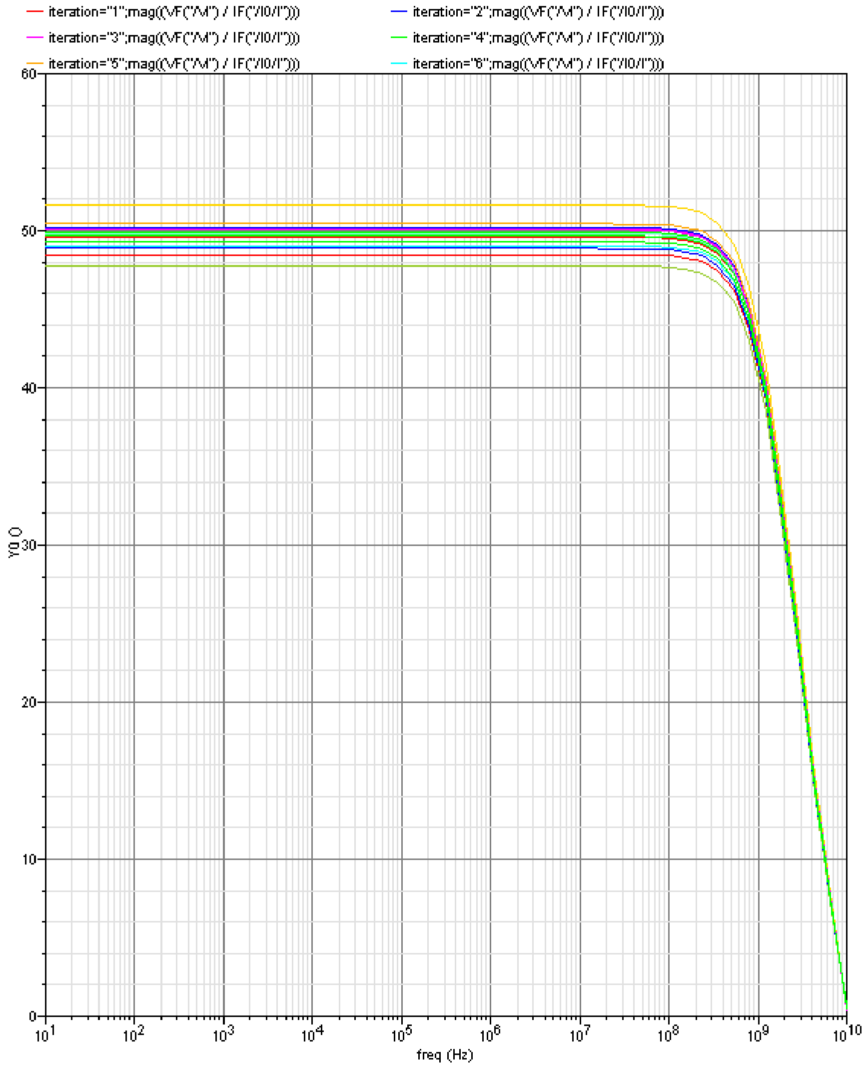
# IV. Cable coupled amplifier

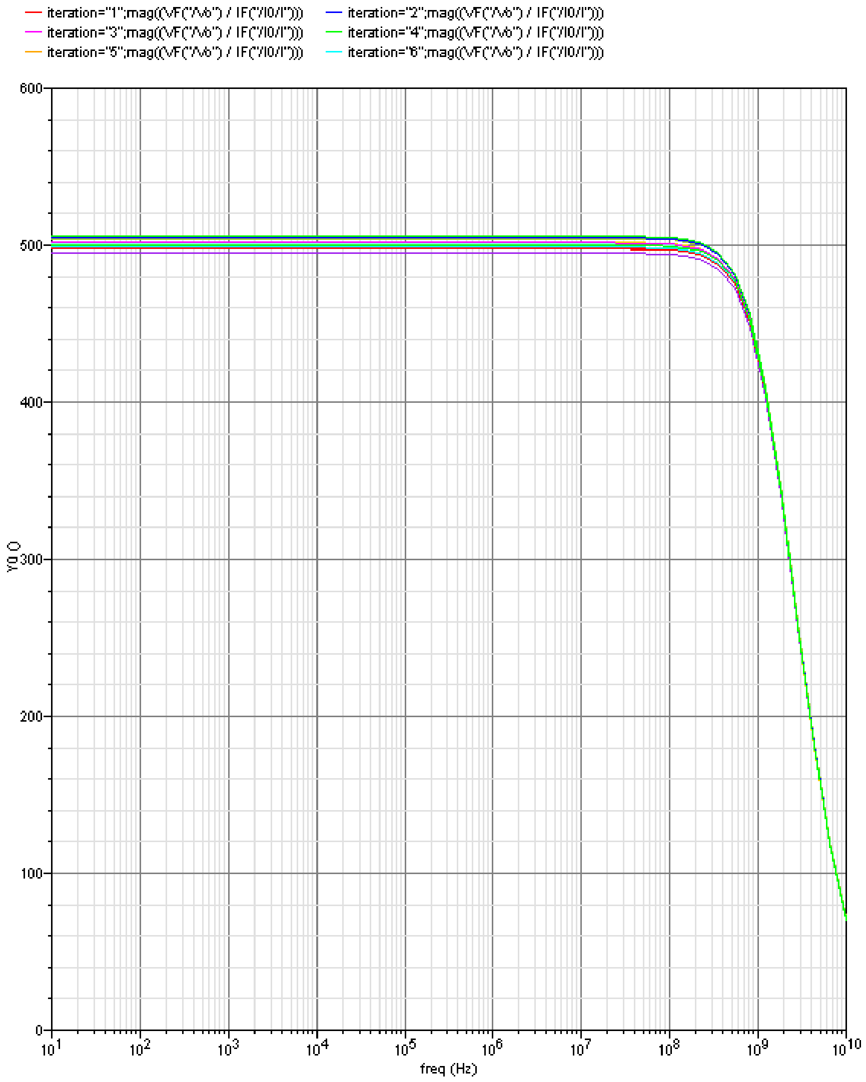
- Noise



# IV. Cable coupled amplifier

- Monte Carlo: Mismatch: no problem





# IV. Cable coupled amplifier

- Process variations: >5% effect, but can be compensated (whole production run)