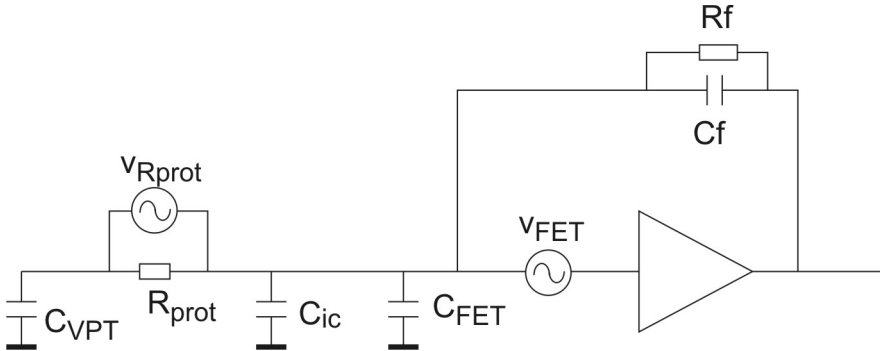


Endcap VFE protection resistor noise considerations

The figure shows an equivalent circuit for the capacitances and noise sources appearing at the input of the MGPA. C_{VPT} , C_{ic} , C_{FET} and C_f represent the VPT capacitance, the interconnect (cable) capacitance and the input FET capacitance respectively. R_{prot} is the proposed protection resistor, with V_{Rprot} its equivalent noise generator $[(4kTR_{prot})^{1/2}]$. V_{FET} models the FET channel thermal noise, and C_f and R_f are the input stage feedback components.



The noise contribution of the protection resistor R_{prot} depends on where it is located in the circuit with respect to the capacitances which determine how much gain the noise it generates is subjected to. Looking at the figure it can be seen that v_{FET} is amplified by a factor C_{TOT}/C_f , whereas v_{Rprot} only sees a gain C_{VPT}/C_f . If C_{VPT} is small then the relative noise contribution of R_{prot} is also small. The noise is given by

$$ENC[electrons] = \frac{2.718}{1.6 \times 10^{-19}} \sqrt{\frac{kTR_{prot}C_{VPT}^2}{2\tau} + \frac{v_{FET}^2 C_{TOT}^2}{8\tau}}$$

where $C_{TOT} = C_{VPT} + C_{ic} + C_{FET} + C_f$ (+ any other stray capacitance).

As an example I choose the following hopefully representative values for the components:

$C_{VPT} = 10$ pF, $C_{ic} = 50$ pF, $C_{FET} = 60$ pF, $C_f = 10$ pF, $R_{prot} = 100\Omega$, $v_{FET} = 0.25$ nV/(Hz)^{1/2} (approximate value consistent with SPICE simulation and extrapolated measurements of real devices).

The protection resistor noise contribution (for $\tau = 40$ ns) is 386e and the input device noise contribution is 976e, both small compared with the feedback resistor noise (~2500e) and the target specification of less than 3500e.

My conclusion is that a protection resistor of this size can be included without a significant noise penalty, but only if it can be located close to the VPT itself. If it were to be included on the motherboard, after the interconnect cable, it would see C_{VPT} and C_{ic} (a total of 60 pF) and its noise contribution would be much larger at 2318e. For comparison the intrinsic noise voltage of a 100 Ω resistor ($4kTR$) is 1.28 nV/(Hz)^{1/2} which you can see is much larger than the input FET noise.