Problem 1

The signal reported in the figure below features $T_P = 200ns$ and a variable amplitude V_P, which is to be measured with high sensitivity. The pulse arrival time can be easily derived from a synchronous auxiliary signal. The sensor producing the signal is readout by means of a preamplifier featuring a wide bandwidth limited by a single pole ($f_{PA} = 500MHz$) and input-referred voltage noise generator (wideband component $\sqrt{S_V} = \frac{5nV}{\sqrt{Hz}}$, B/f^2 component with $f_C = 10MHz$). The signal source is stable for at most 12 hours, then it must be replaced and the system is reset.

a) Discuss the ideal optimum filtering strategy for this problem, clearly pointing out the weighting function that should be applied to obtain the best possible SNR (note: the computation of the SNR is NOT required). Then, evalutate **quantitatively** the sensitivity that could be achieved with a practical filter implementation featuring one gated integrator, providing full details on the sizing of filter parameters. Calculate the minimum amplitude V_P that could be measured with this practical solution.

b) Consider now that the noise introduced by the preamplifier features a B/f^3component instead of the B/f^2 , with the same corner frequency. Discuss the effect of this new noise spectrum on the solution of point a). How would the answer change if you could use two integration windows and any necessary linear electronics? Provide a quantitative evaluation in both cases computing the minimum pulse amplitude that could be measured.

c) Considering a constant signal and only white noise, provide a comparison, from a theoretical point of view, between analog and digital filtering in the **time domain** as a function of the sampling frequency.